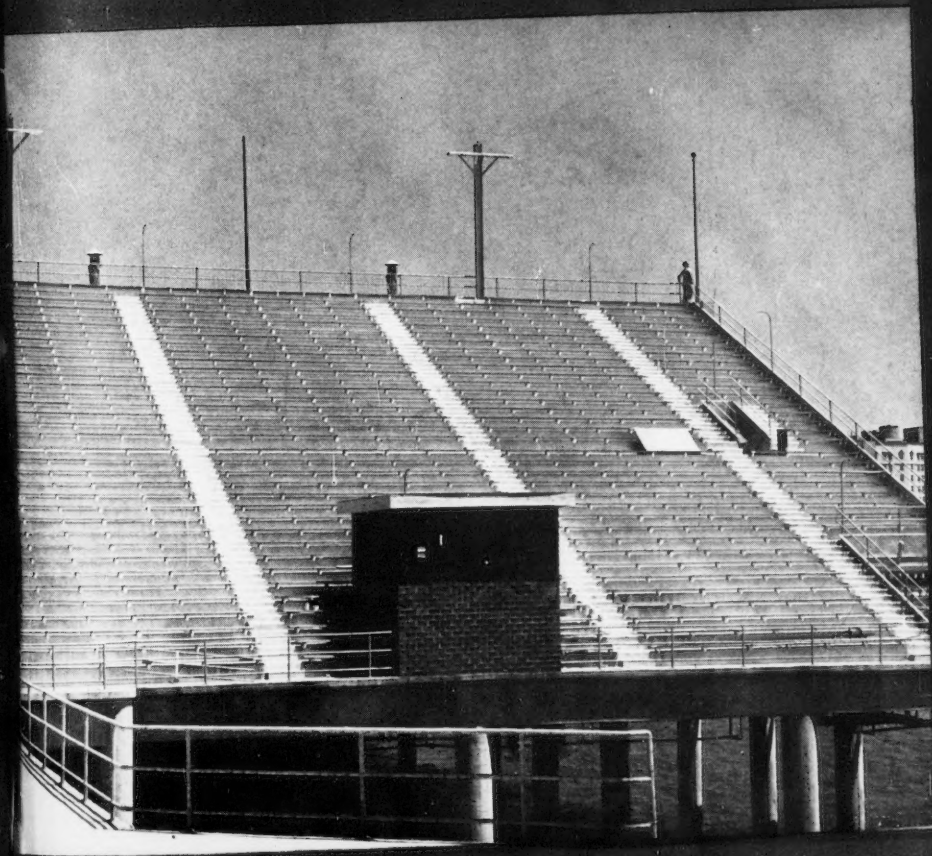
Corrosion

OFFICIAL PUBLICATION
NATIONAL ASSOCIATION OF CORROSION ENGINEERS



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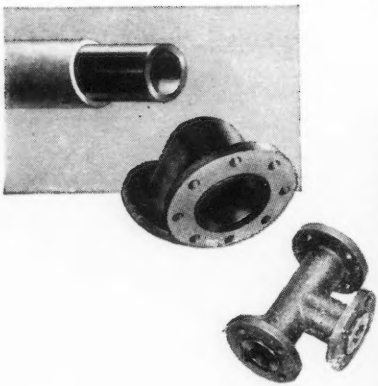

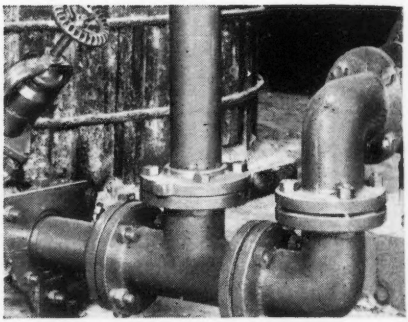

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VOLUME 4
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Corrosion

devoted entirely to

CORROSION
Research and Control

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THIS MONTH'S COVER

• *Not a test rack, but the steel stadium at the end of the Galveston, Texas, Pleasure Pier, 1000 feet out in the Gulf of Mexico. Structures of this kind demand proper surface protection from the effects of salt spray, wind and sun. This photograph was supplied by John W Nee of the Napko Paint and Varnish Works, Houston, Texas, whose article on corrosion resistant paint may be found on page 599 this issue.*

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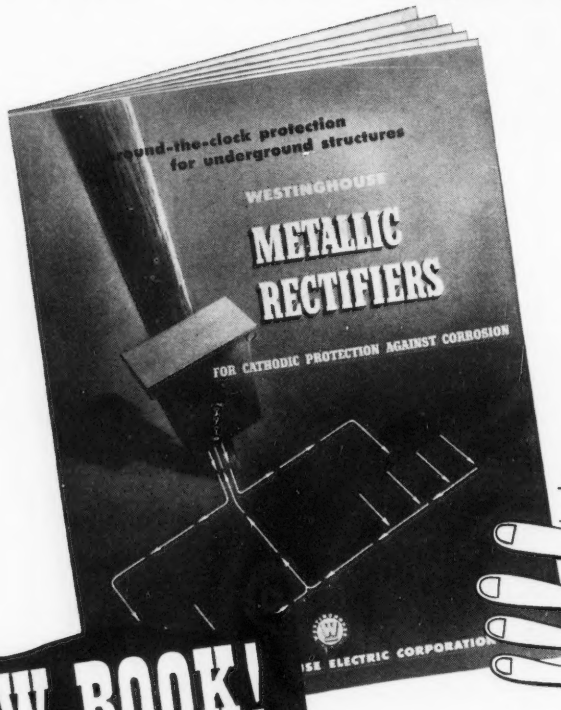

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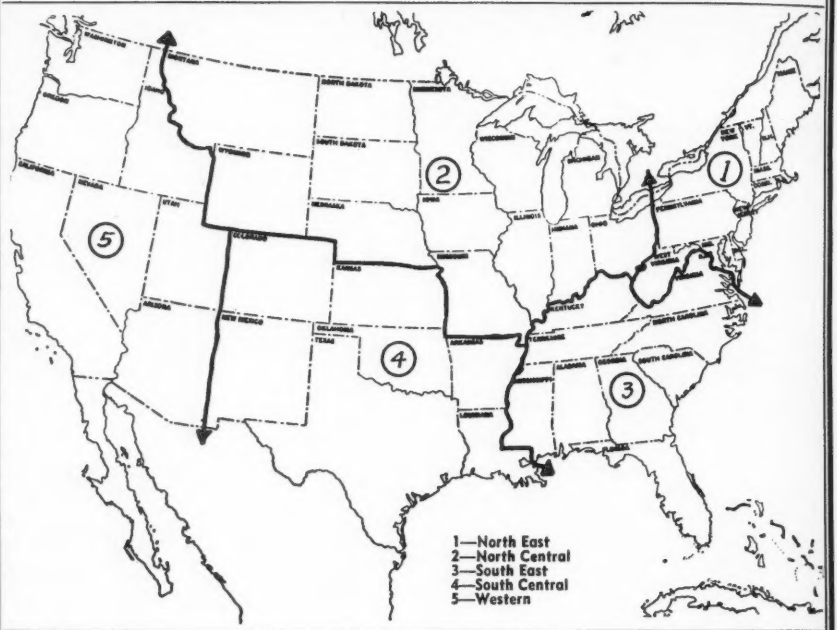

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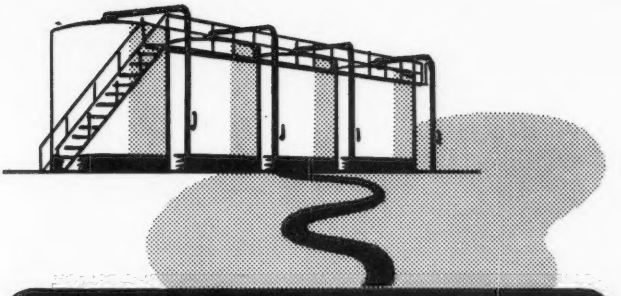

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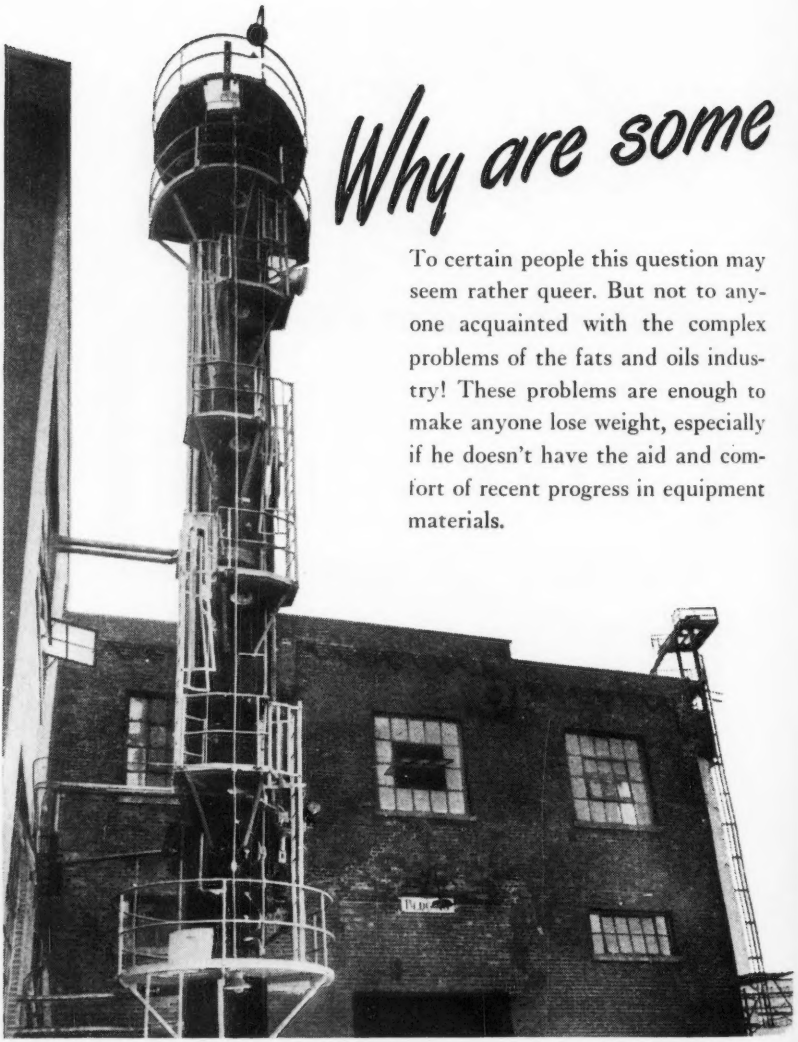

A countercurrent fat splitting column operated at a pressure of 700 psi and at a temperature of 500° F. The column has an inside diameter of 28 inches and is approximately 60 feet in height. To resist the corrosive effect of the reagents at the high temperature and pressure indicated, the vessel was fabricated by A. O. Smith Corporation, Milwaukee, Wisconsin, with an inner shell of Inconel, contained in a steel vessel of laminated construction. The total wall thickness is 1-7/16". Photo courtesy of Emery Industries, Inc. and Blaw-Knox Co.

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The Corrosion Fly in the Ointment

Naturally, the making of these new products brings along a number of new corrosion problems. Fatty acids at high temperature are quite corrosive to many common equipment materials. The material chosen for equipment must not introduce harmful impurities, must give long and dependable service life often at high temperatures and pressures, and must be suitable for shop and field fabrication. Our experience in helping the fatty acid industry solve such problems is available to you. Send for a copy of the *Corrosion Data Work Sheet*, which is designed to clarify the essential factors.

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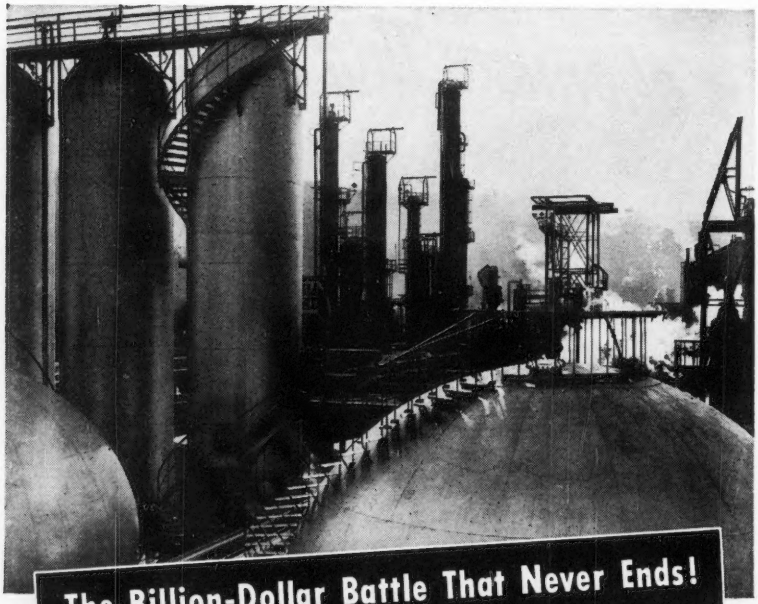

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A Message from Your Officers

This Month's Contributor

O. C. MUDD, *Treasurer, NACE*

DECEMBER is synonomous with Christmas and Christmas is the season commemorated to good will and giving. We are prone to reckon our Christmas gifts in terms of something purchased causing us to lose sight of that gift from which Christmas originates—a gift of unselfish service to humanity.

This gift of unselfish service was dedicated to a way of better living and many others during succeeding ages have dedicated unselfish services in a chosen field of endeavor that their fellowmen might benefit from their efforts.

The accomplishments of individuals or groups thus dedicated to service have added to the upward steps in progress leading to our present civilization; most of these steps were added by individuals during the past.

Each step along the way of progress has increased the complexity of adding the next until most present day additions are accomplished by group effort.

Our association is dedicated to an important phase of progress—helping to build another step by stopping or at least curtailing the enormous losses exacted by corrosion. Stopping these losses can lead to a better way of living.

Most rapid advancement in reducing corrosion will be realized by contributed efforts of our members according to their ability. Any contributed effort, given without thought of return will be a service to our fellowmen and a determination to render such service should bring you a Merry Christmas.

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) to promote scientific research in determining the causes of corrosion and methods of its control with respect to theory and practice.

(b) to provide a means of exchange of knowledge and ideas among those individuals actively engaged in the control of corrosion.

(c) to promote methods of control of corrosion.

(d) to promote standardization of terminology, methods, equipment and design in the development of methods of corrosion control.

(e) to foster cooperation between individual owners of metallic structures in the solution of their joint corrosion problems.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers are nominated by (1) the Board of Directors, or (2) a quorum of at least 25 members, and elected by the membership.

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Environmental pH as a Factor in Control of Anaerobic Bacterial Corrosion*

*By J. B. Hunter, H. F. McConomy and R. F. Weston**

INCREASING evidence is being found that anaerobic corrosion of the external surface of pipelines is a serious problem in widely scattered localities. In 1939 Hadley[1] reported widespread anaerobic corrosion in Ohio and Pennsylvania. In 1940 Hadley[2] and in 1941 Beckwith[3] published extensive studies on this type of corrosion. In 1945 and 1947 Starkey and Wight[4, 5] reported conditions favoring microbial corrosion in soil and information concerning the mechanism of the corrosion process. In 1947, Huddleston[6] presented results obtained by cathodic protection of a pipeline located in Oklahoma which was rapidly deteriorating from bacterial corrosion.

Anaerobic corrosion, according to the latest concept, is caused by specific types of bacteria which are active only in environments free of oxygen (anaerobic). Other factors which affect the action of the bacteria are moisture content of the soil, the alkalinity or environmental pH, abundance of organic matter and presence of salts required as nutrients for growth of the bacteria. One of the theories concerning the mechanism of anaerobic corrosion is that the principal action of the bacteria is to depolarize the pipe by removal of cathodic hydrogen normally present when iron is in contact with water. The bacteria make use of the sulfate present in the soil adjacent to the pipe to oxidize the cathodic hydrogen. The sulfate, in turn, is reduced to sulfide which can be detected as hydrogen sulfide. This sulfide reacts further with the ferrous iron of the pipe to produce ferrous sulfide. Thus growth of these bacteria is accompanied by the formation of hydrogen sulfide and anaerobic corrosion is characterized by the presence of ferrous sulfide in the products of corrosion.

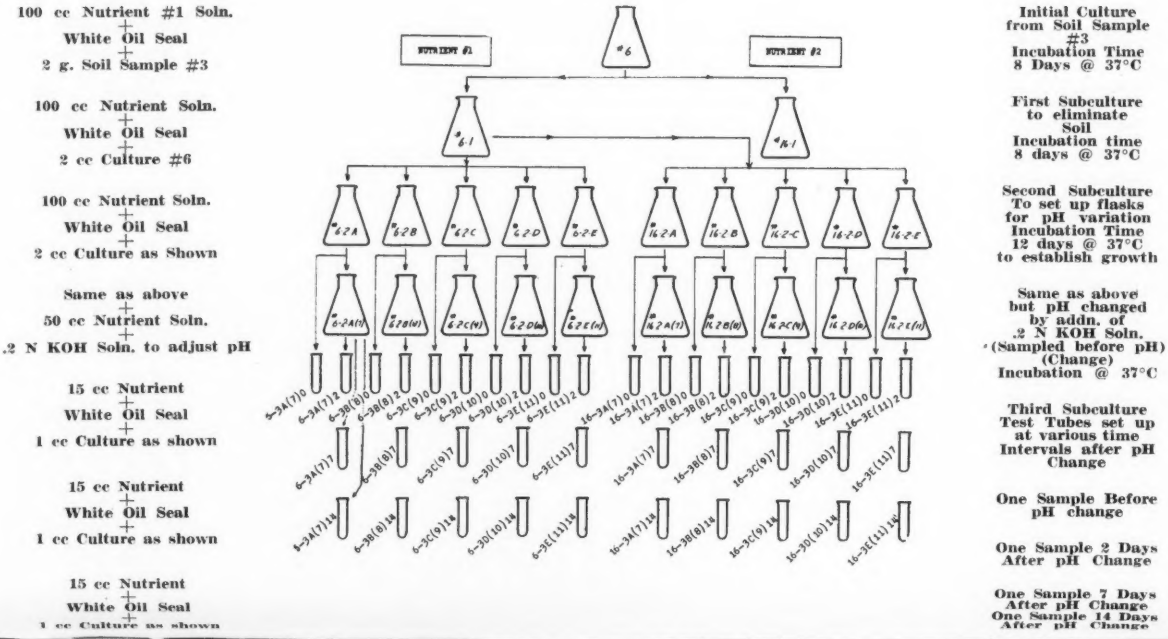
Since control of the alkalinity or environmental pH of the soil surrounding a pipeline might be a practical method for inhibiting anaerobic corrosion, it was the purpose of these experiments to determine what effect increasing

★ Presented by Pipe Line Technology Committee of the A.P.I. at the Meeting in Chicago, Nov. 9, 1948.

* The Atlantic Refining Co., Philadelphia, Penna.

Figure 1

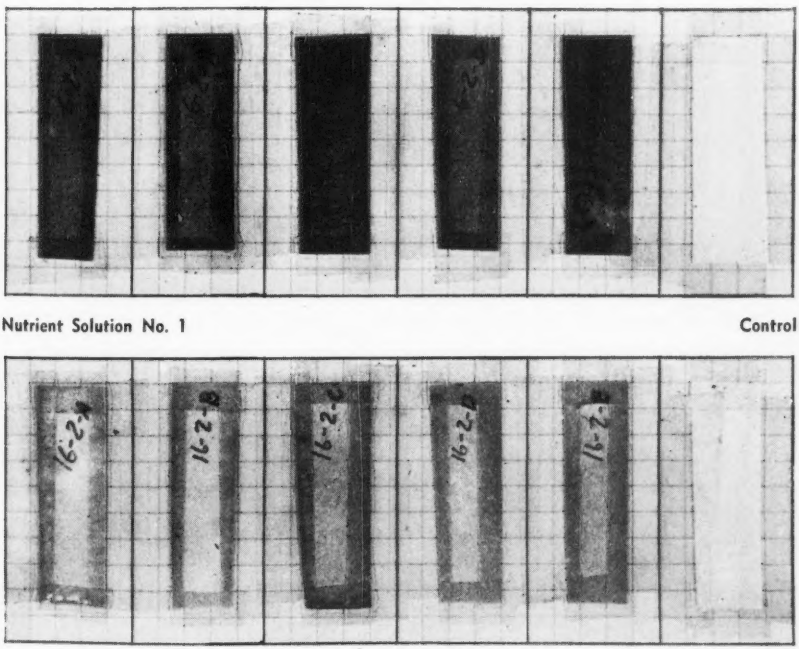
Culture Scheme for Evaluating the Effect of Nutrient pH on the Development of Sulfate Reducing Bacteria.
Soil Sample #3


100 cc Nutrient #1 Soln.
White Oil Seal
2 g. Soil Sample #3
100 cc Nutrient Soln.
White Oil Seal
2 cc Culture #6
100 cc Nutrient Soln.
White Oil Seal
2 cc Culture as Shown
Same as above
50 cc Nutrient Soln.
.2 N KOH Soln. to adjust pH
15 cc Nutrient
White Oil Seal
1 cc Culture as shown
15 cc Nutrient
White Oil Seal
1 cc Culture as shown
15 cc Nutrient
White Oil Seal
1 cc Culture as shown
NUTRIENT #1
#6
NUTRIENT #2
#6-1
#16-1
#6-2A
#6-2B
#6-2C
#6-2D
#6-2E
#16-2A
#16-2B
#16-2C
#16-2D
#16-2E
Initial Culture from Soil Sample #3 Incubation Time 8 Days @ 37°C
First Subculture to eliminate Soil Incubation time 8 days @ 37°C
Second Subculture To set up flasks for pH variation Incubation Time 12 days @ 37°C to establish growth
Same as above but pH changed by addn. of .2 N KOH Soln. (Sampled before pH) (Change) Incubation @ 37°C
Third Subculture Test Tubes set up at various time Intervals after pH Change
One Sample Before pH change
One Sample 2 Days After pH Change
One Sample 7 Days After pH Change
One Sample 14 Days After pH Change

the environmental pH or alkalinity would have on the growth of these sulfate reducing bacteria. The literature contains references pertinent to the problem but leaves unanswered a number of questions of importance for such control. Bunker[7] found these organisms to develop between pH 5.0 and 9.0. Rittenberg[8] has reported the range for development of a salt water strain to be pH 5.4 to 8.5. Similar results were obtained by Starkey and Wight[4] in their studies with *Sporovibrio Desulfuricans*. With the exception of some inconclusive evidence presented by Bunker[7] no data appear which illustrate the effect of environmental pH values higher than 9.0.

More specifically, it is the purpose of this article to answer two questions which arise in any consideration of environmental pH as a factor in anaerobic bacterial corrosion control. The first question of primary importance involves the toxicity of a high pH environment to the sulfate reducing bacteria. That is to say, does a pH above 9.0 exert a bacterial or merely a bacteriostatic effect on the bacteria. As

Figure 2
Development of Sulfate Reducing Cultures Before pH Increase.
Incubation Time—12 Days at 37° C.
Lead Acetate Paper Exposure Time—12 Days

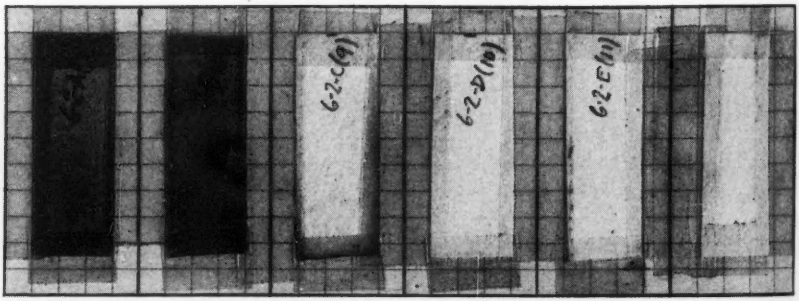


employed in this paper, bactericidal means the permanent destruction of the bacteria as far as their sulfate reducing activity is concerned. Bacteriostatic means the creation of a temporarily inactive state of the bacteria. Assuming the effect of a high pH to be only bacteriostatic and not bactericidal, the second question is concerned with the pH level at which growth will reoccur after having been arrested. The first question is considered in Part I of the following discussion whereas Part II presents some evidence relative to the second problem.

PART I
Bacteriostatic vs. Bactericidal Action of High pH

The culture of sulfate reducing bacteria used throughout this work was obtained by incubation of a 2.0 gram sample of soil obtained from a region in Eastern Pennsylvania where anaerobic bacterial action had been particularly prevalent. Two other soil samples from other similar locations also were used as a source for starting the cultures, however bacterial growth in these cases appeared somewhat less active than in the first sample. Two nutrient solutions also were tested

Figure 3
Development of Sulfate Reducing Cultures After pH Increase
Incubation Time—2 Days at 37° C.
Lead Acetate Paper Exposure Time—2 Days



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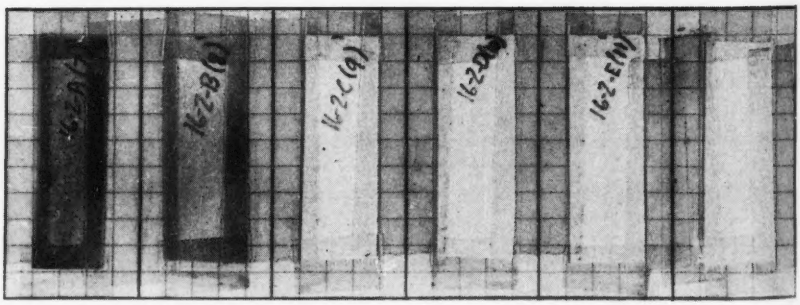


Nutrient Solution No. 2 Control

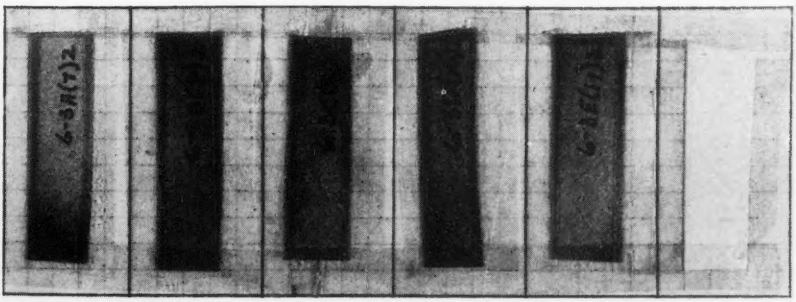
as starting media. Nutrient No. 1 contains both calcium and magnesium salts whereas Nutrient No. 2 contains neither of these elements. The composition of these culture media is given in Table I.

TABLE I

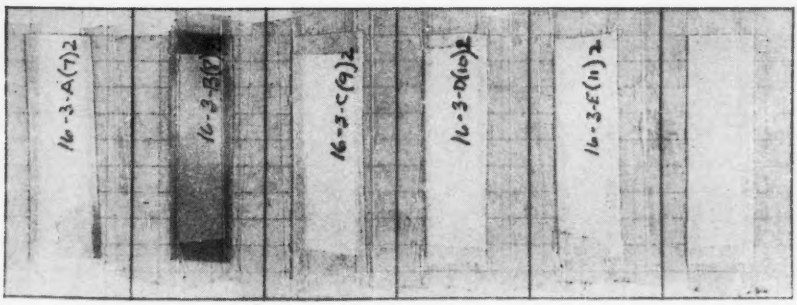
	Nutrient No. 1	Nutrient No. 2
Tap Water	1000 ml.	1000 ml.
NH_4CL	1.00 Gm.	....
$MgSO_4 \cdot 7H_2O$	2.00	....
Na_2SO_4	0.44	....
$K_2H\ PO_4$	0.50	0.50
$CaCl_2 \cdot 2H_2O$	0.10	....
Mohr's Salt	Trace	Trace
Na-Lactate	3.50	5.00
$(NH_4)_2\ SO_4$	....	2.00
Approximate pH	7	7

Nutrient No. 2 was included in this study only because of the uncertainty at the start of this work as to the subsequent effect of high pH on the precipitation of Ca and Mg which might influence the growth of the sulfide reducing bacteria. It will be seen from the results of this study that the presence of both Ca and Mg salts in the nutrient markedly affect the rate of bacterial development. Nutrient No. 1 therefore was employed exclusively in Part II whereas both solutions were used in Part I.

Figure 4
Development of Test Tube Cultures 2 Days After pH Increase.
Incubation Time—11 Days at 37° C.
Lead Acetate Paper Exposure Time—11 Days



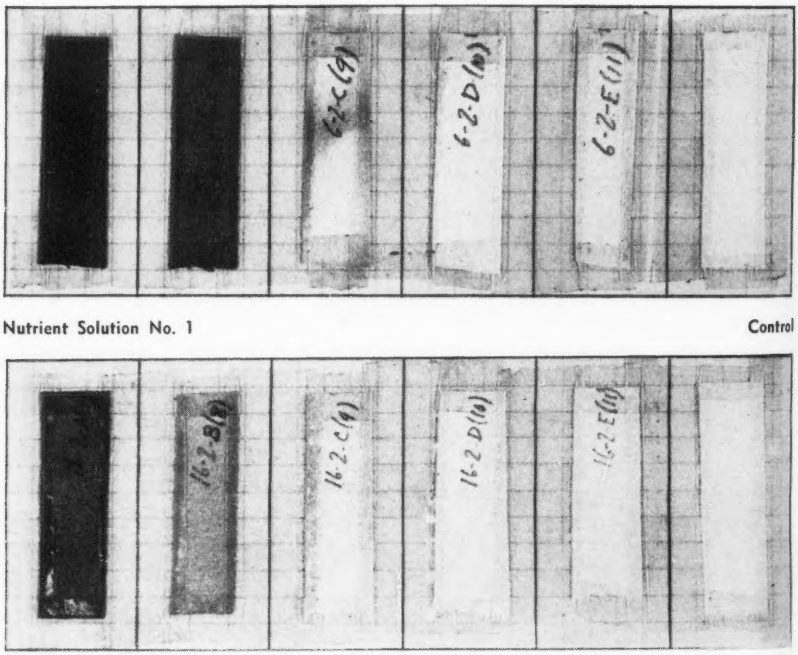
Nutrient Solution No. 1 Control



Nutrient Solution No. 2 Control

Following incubation of the original soil sample in Nutrient No. 1 for several days, 2 ml. of the liquid culture was transferred to each of two flasks No. 6-1 and No. 16-1 containing 100 ml. Nutrient No. 1 and No. 2, respectively. The culture transfer scheme followed in Part I is shown in Figure 1. Incubation of these two flasks No. 6-1 and No. 16-1 developed two soil free cultures. Because of the stronger growth developing in flask No. 6-1, 2 ml. of liquid culture was transferred from flask No. 6-1 to each of 10 flasks. Five flasks, No. 6-2-A to No. 6-2-E contained Nutrient No. 1 while the second five flasks No. 16-2-A to No. 16-2-E contained Nutrient No. 2. Incubation for 12 days at 37° C. again established a strong growth of sulfate reducing bacteria in each flask of both series. With growth well established a predetermined amount of 0.2 N.KOH was added to each of four flasks in each set to create environments of higher pH having nominal values of 7, 8, 9, 10 and 11, respectively. After two days incubation at these increased pH levels, liquid samples from each of the 10

Figure 5
Development of Sulfate Reducing Cultures After pH Increase
Incubation Time—7 Days at 37° C.
Lead Acetate Paper Exposure Time—5 Days



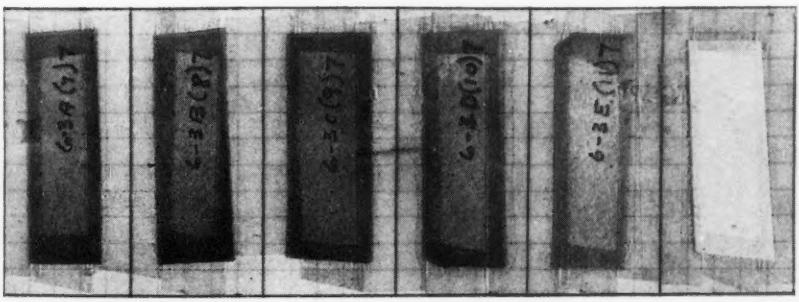
Nutrient Solution No. 1 Control

Nutrient Solution No. 2 Control

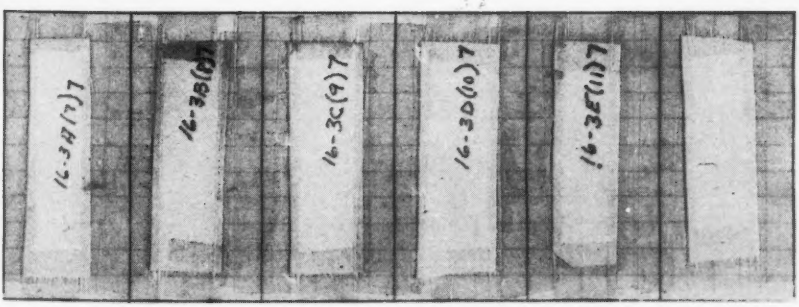
flasks were transferred to test tubes containing the original nutrient mediums. Transfers to test tubes also were made from the environmental pH flasks after 7 days and after 14 days of incubation. The development of growth during incubation in these test tubes served as an indication of the bactericidal or bacteriostatic nature of the high environmental pH.

In order to illustrate results of these experiments, use has been made of the chemical reaction accompanying bacterial growth. Sulfate reducing bacteria develop through the reduction of sulfates to hydrogen sulfide. Detection of the formation of hydrogen sulfide through the use of moist alkaline lead acetate paper exposed to the vapor phase above the culture has been taken therefore as a criterion of bacterial activity. This simple method of detecting positive formation of hydrogen sulfide was selected because of its high sensitivity and because it offers a convenient and expedient way of presenting the results of the study in a qualitative or semi-quantitative manner depending on the degree of darkening of the test papers. Photographs of these test papers are

Figure 6
Development of Test Tube Cultures 7 Days After pH Increase.
Incubation Time—12 Days at 37° C.
Lead Acetate Paper Exposure Time—7 Days



Nutrient Solution No. 1 Control



Nutrient Solution No. 2 Control

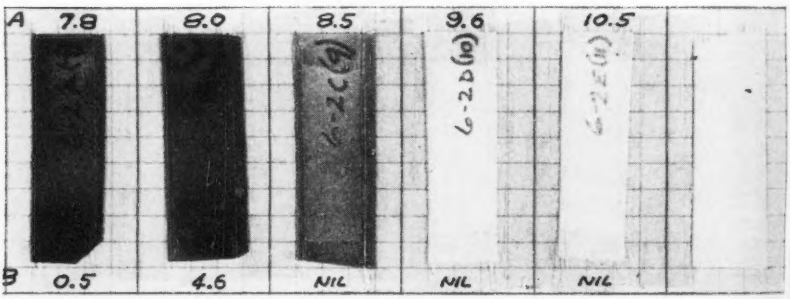
included in this report and illustrate the effects of environmental pH on the growth of the sulfate reducing bacteria.

The exposure time of the test papers above the cultures is recorded on each photograph.

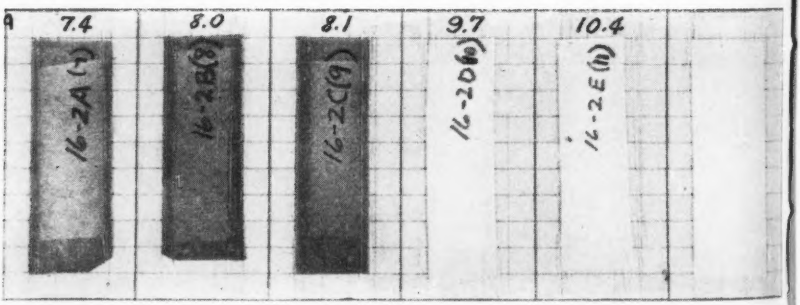
Throughout this investigation extreme care was exercised to prevent contamination of the various culture flasks and tubes. All culture media and sealing oil were steam sterilized carefully before use and transfers of cultures were made under sterile conditions. Since it was the purpose of the investigation to study the bacteria as they exist in a typical corrosive soil, no attempt was made to isolate a pure sulfate reducing culture of *Sporovibrio Desulfuricans.*

At the end of the experiment, samples were removed from each flask for pH determination. One set of samples from the Nutrient No. 1 series was also examined for sulfide ion concentration since under basic conditions the sulfide ion may have remained in solution instead of appearing as hydrogen sulfide in the gas phase. Had these determinations not been made, a

Figure 7
Development of Sulfate Reducing Cultures After pH Increase.
Incubation Time—14 Days at 37° C.
Lead Acetate Paper Exposure Time—7 Days



Nutrient Solution No. 1 Control



Nutrient Solution No. 2 Control

(A)—Experimental pH Values. (B)—Sulfide Ion conc. mgs/100 cc.

question could have been raised as to whether the bacteria actually were inactive at high pH levels or whether the method of detecting activity gave false information under these conditions.

Results of this study are illustrated in Figures 2 to 8, inclusive. In each of these figures the top row of test strips represents the results of growth in flasks or test tubes containing Nutrient No. 1 while the second row shows occurrence of growth in flasks or tubes containing Nutrient No. 2. Figure 2 shows the development of a strong sulfate reducing growth in all flasks prior to the change in pH of the media. It may noted, however, that the absence of Ca and Mg salts in Nutrient No. 2 has markedly affected the activity of the bacteria. Before altering the pH of the culture media the vapor phase of all the flasks was carefully purged with sterile nitrogen so as to more properly evaluate the continuance of growth after the change. In Figure 3 are presented the results of bacterial growth two days after making the pH change in the cultures. From left to right

Figure 8
Development of Test Tube Cultures 14 Days After pH Increase.
Incubation Time—11 Days at 37° C.
Lead Acetate Paper Exposure Time—11 Days

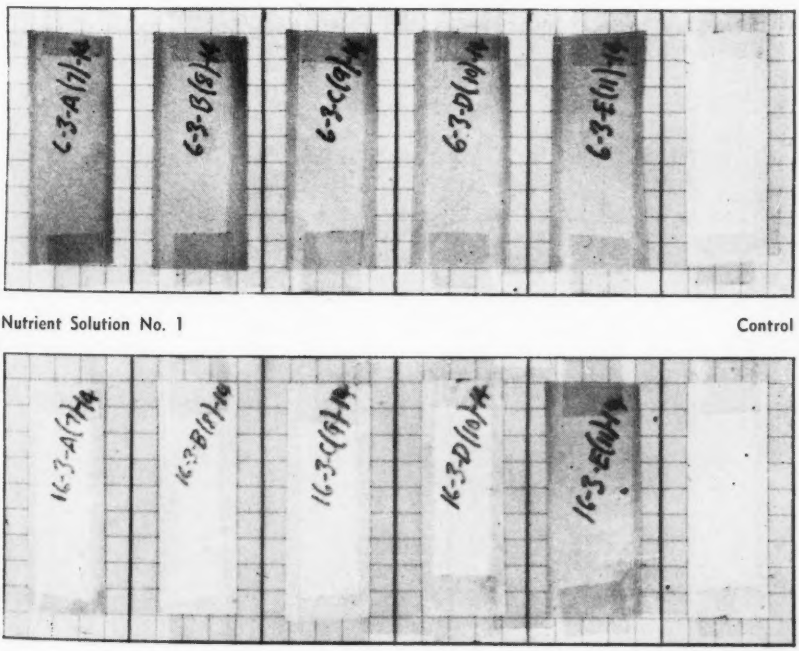
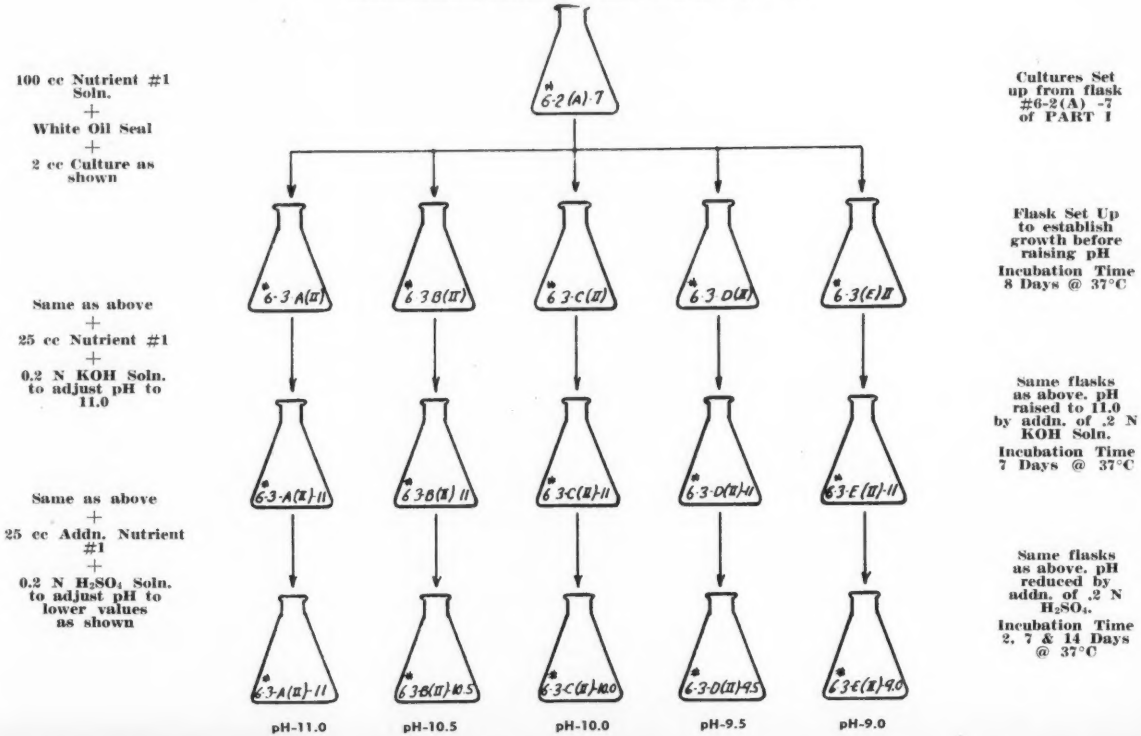


Figure 9
Culture Scheme for Evaluating the Effect of Falling pH on the Development of Sulfate Reducing Bacteria Previously Arrested at pH-11.0.



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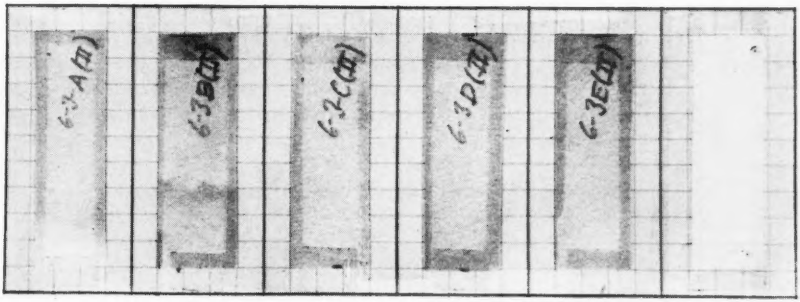
nominal pH values are 7, 8, 9, 10 and 11, respectively. Here it should be observed that growth has continued at pH of 7 and 8 and has been markedly reduced at pH of 9. At values of 10 and 11 growth appears to have ceased.

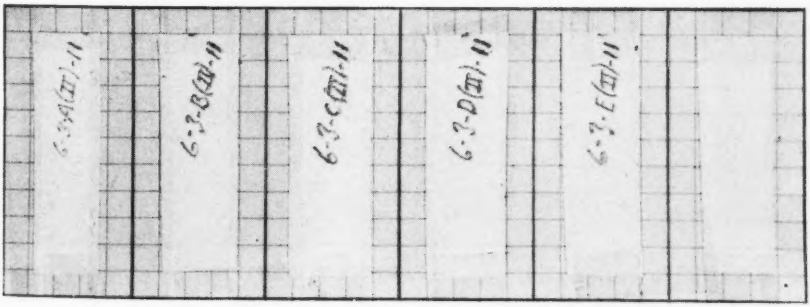
After this two-day period of incubation at increased pH levels, samples of each culture were transferred to test tubes containing the corresponding fresh nutrient solution (pH of 7). Results after 11 days more incubation in the test tubes are illustrated in Figure 4 and show a uniform growth in each case. The interpretation of this reoccurrence of growth in tubes inoculated from flasks at pH of 10 and 11 indicate a bacteriostatic rather than a bactericidal action at these high pH levels. A similar examination was made of the bacterial growth after exposure at the increased pH levels for incubation times of 7 and 14 days. The results are shown in Figures 5, 6, 7 and 8, respectively. A comparison with

Figure 10
Development of Sulfate Reducing Cultures Before pH Increase.
Incubation Time—8 Days at 37° C.
Lead Acetate Paper Exposure Time—8 Days



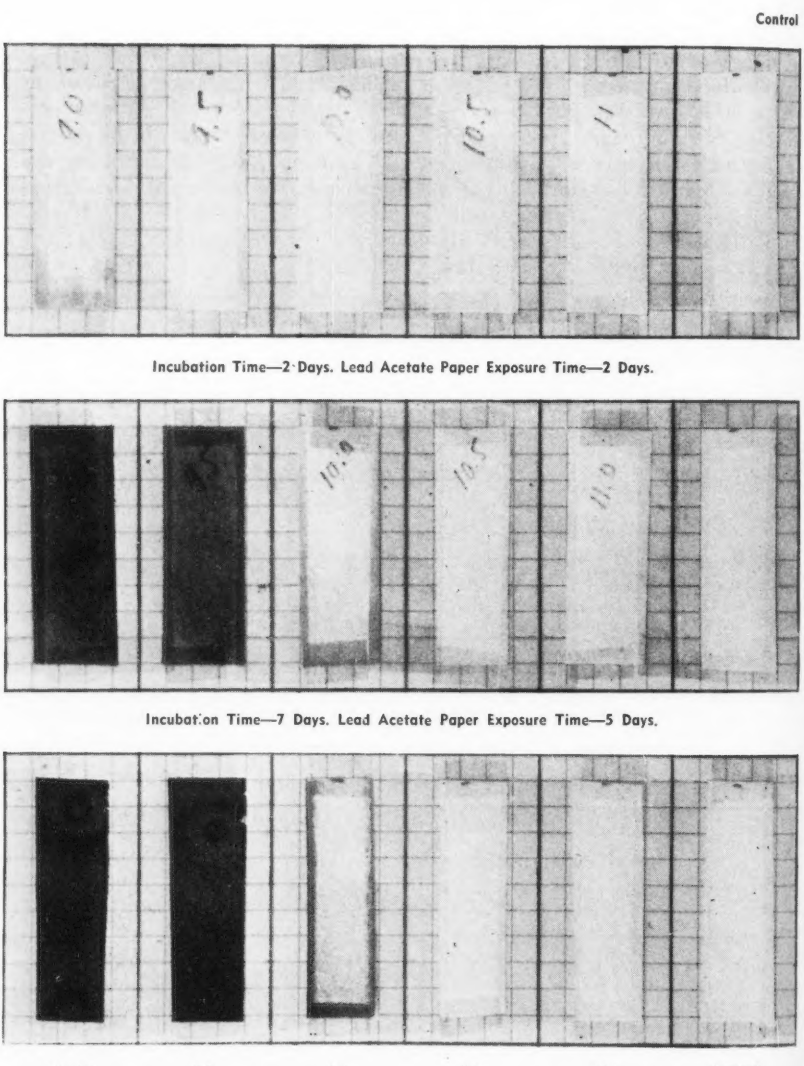
Control

Figure 11
Development of Sulfate Reducing Cultures After pH Increase.
Incubation Time—7 Days at 37° C.
Lead Acetate Paper Exposure Time—7 Days



Control

Figure 12
Development of Sulfate Reducing Cultures After pH Decrease.



Incubation Time—2 Days. Lead Acetate Paper Exposure Time—2 Days.

Incubation Time—7 Days. Lead Acetate Paper Exposure Time—5 Days.

Incubation Time—14 Days. Lead Acetate Paper Exposure Time—7 Days.

(A)—Measured pH after 14 days.

the results described above indicate further substantiation of the bacteriostatic nature of this treatment—at least up to an incubation period under these conditions of two weeks duration. On Figure 7 are given the pH values as experimentally measured in each environmental flask at the end of the experiment together with the results of the sulfide ion determination.

PART II

Growth Reoccurrence After Exposure at High pH

The general treatment of this problem has been the same as that employed in Part I. In this case only Nutrient No. 1 was used. The transfer scheme, however, is less extensive than that employed in Part I and is shown in Figure 9. Uniform growth was established in each of the five flasks. The pH of each flask was then raised to the same high pH value necessary to insure complete cessation of sulfate reducing activity. After one week exposure at the high pH level, 0.2 N H_2SO_4 was added to each flask in such amount as to establish a nominal pH series of 9.0, 9.5, 10.0, 10.5 and 11.0. The flasks were then incubated at 37° C. and examined for reoccurrence of growth after periods of two days, seven days and fourteen days. At the end of fourteen days, samples were removed from each flask and pH values accurately determined.

Results of this experiment likewise are illustrated through the use of lead acetate test strips. In Figure 10 the development of a uniform growth in each flask is illustrated by the uniform darkening of the test papers. Figure 11 clearly shows the bacteriostatic action occurring after a pH increase to above 10. In Figure 12 may be seen the nature of the growth reoccurrence two, seven and fourteen days after again lowering the pH level to nominal values of 9.0, 9.5, 10.0, 10.5 and 11.0 with 0.2 N H_2SO_4. After a fourteen day exposure actual pH values of each culture medium was measured by means of the usual glass-calomel electrode method.

In addition to illustrating again the bacteriostatic effect of high pH, these results further substantiate the results of Part I wherein the threshold of bacteriostatic action is indicated to lie somewhere in the range of 9.0 to 9.5 pH.

Results of this study indicate that control of the alkalinity of the soil adjacent to a pipeline could be used to inhibit anaerobic corrosion by arresting the active growth of the sulfate reducing bacteria. Such control of the alkalinity of the soil might be accomplished in the field by electrical or chemical means. Further development of such methods of control would be necessary to determine their effectiveness, particularly on surfaces where reduction in the electrical film resistance of the metal has occurred by prior bacteria attack.

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3. Beckwith, T. D., The Bacterial Corrosion of Iron and Steel, J. Amer. Water Works Assoc. **33**, 147-167 (1941).
4. Starkey, R. L., and Wight, K. M., Final Report of the Amer. Gas Assoc. Iron Corrosion, Research Fellowship (1945).
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8. Rittenberg, S. C., Studies on Marine Sulfate-Reducing Bacteria, thesis, University of California, p. 115 (1941).

DISCUSSION

*By Raymond F. Hadley**

Under the summary it is stated in the first sentence "A study has been made of the effect of environmental pH on the growth of sulfate reducing bacteria as it concerns the control of anaerobic bacterial corrosion." I do not believe the effect of environmental pH, as it concerns the control of anaerobic bacterial corrosion, has been demonstrated in the paper. It appears to me that the study pertains more to the effect of environmental pH upon the development and growth of the sulfate reducing bacteria. In this connection it may be well to define micro-biological corrosion, for such corrosion may occur either directly or indirectly as the result of the metabolic activity of the microorganisms under consideration. In other words, if the corrosion phenomena associated with the development of the sulfate reducing bacteria exists only so long as these microorganisms are active, then the title of the paper may well be correct, however, it should be pointed out that if the products resulting from their metabolic activity persist, even after the sulfate reducing bacteria cease to develop, corrosion may still continue, at least for a limited period of time, irrespective of whether or not the bacteria are present.

In one of my papers[3] experiments were reported which demonstrated that the sulfate reducing bacteria not only caused an appreciable reduction in the electrical film resistance of the metal at the metal-solution interface, but also, even long after the sulfate reducing bacteria cease active development, relatively cathodic potentials of what must have been the surface film of the metal were observed (approximately 365 millivolts hydrogen scale).

The similarity in chemical activity of oxygen and sulphur would suggest the ferrous metal was covered with a cathodic sulfide film, possibly FeS, or perhaps Fe_2S_3 as would be expected by comparison with the oxide films formed on ferrous metal. What I am endeavoring to point out is the effect of environmental pH as reported in the paper is more concerned with the activity of the sulfate reducing bacteria themselves than with the control of bacterial corrosion, particularly where such corrosion already has occurred.

On page 567 in the second sentence of the second paragraph the other factors (other than oxygen) which affect the activity of the sulfate reducing bacteria are mentioned as "moisture content of the soil, the alkalinity or environmental pH, abundance of organic matter containing sulphur and the presence of salts required as nutrients for growth of the bacteria." The organic matter need not, as indicated, contain sulphur. One of the most common sources of organic matter in the soil is, in fact, cellulose, which does not contain sulphur. It will, furthermore, be noted that the nutrient used in the experiments reported in this paper contained sodium

* Susquehanna Pipe Line Co., Philadelphia, Penna.

lactate as the only organic source which does not contain sulphur. The sulphur source is sulfate.

The sentence in this same paragraph beginning "The sulfate, in turn" should, I believe, be further clarified. The studies of von Volzogen Kuhr, particularly in regard to his conclusions based upon analyses of the ferrous corrosion products resulting from microbiological anaerobic corrosion, are especially enlightening and convincing.

In the second sentence of the first paragraph on page 573 it is noted that formation of hydrogen sufide was detected by the use of moist alkaline lead acetate paper exposed to the vapor phase above the culture solution, which test has been taken as a criterion of bacterial activity. This test might be subject to criticism as being more of a qualitative test than a quantitative test. The elimination of the vapor phase and analysis for total sulfide content of the nutrient culture solution in each flask or an actual count of the sulfate reducing microorganisms, had the work been carried out with pure cultures, would perhaps have been more significant.

On page 575 in the paragraph beginning "It may be noted" it is mentioned that the absence of calcium and magnesium salts in nutrient solution 2 has markedly affected the activity of the sulfate reducing bacteria. While the data contained in the paper appear to substantiate this conclusion, I, for one, would be extremely hesitant in accepting such a conclusion from the limited number of experiments which appear to have been performed. Variations in the microbiological population due to seeding, slight changes in oxygen, pH and salt concentrations have, in our work, been shown to have a pronounced effect.

References

1. "The Influence of Sporovibrio Desulfuricans on the Current and Potential Behavior of Corroding Iron," prepared for Bureau of Standards Corrosion Conference, 1943.

By Kent M. Wight*

The general form of the paper is correct and the experimental data obtained have been presented well.

There are some criticisms of the work, however, which I should like to bring out. The criterion of growth of the sulfate-reducing bacteria — namely, use of lead acetate papers — is in general not a good one because if appreciable amounts of iron are in the medium to precipitate out the sulfide formed, in some cases no blackening of the lead acetate papers would occur.

On page 574 no mention is made of the method used for determining the quantity of sulfide produced in the cultures. The quantities produced in the cultures as recorded in Figure 7 are extremely low if the authors consider that the growth obtained was good. Production of at least 100 mg of sulfide sulfur per liter by sulfate-reducing bacteria is considered fair growth under the conditions specified by the authors.

Results of the research are interesting and supply information on a subject which has been studied thoroughly.

* National Cancer Institute, U. S. Public Health Service, Bethesda, Md.

Punched Cards for Filing Corrosion Test Results*

*By Lorraine R. Voigt**

INTRODUCTION

FOR THE USE of Corrosion Engineering Section of The International Nickel Co., Inc., a file is kept of the numerical results of corrosion tests made by Inco, or by others as reported in technical literature. All these data are recorded on standard forms as illustrated in Figure I. Here all the test conditions are described at the top of the form, while the test results, converted to standard units for sake of easy comparison of results of different tests, are recorded at the bottom of the form. Note that the results include weight losses and also the depth of pitting as it occurs on the main surface of the specimens or under the Bakelite insulating spacers (crevice corrosion).

Until recently these forms were filed in alphabetical order determined by the principal chemical in which the tests were run. Cross-reference sheets were used for cases where the data referred to chemical mixtures, and no effort was made to file by concentration, temperature, or any other test condition.

By the time about 300,000 items of corrosion data had been accumulated, however, it became increasingly evident that the usefulness of the file was being restricted by the difficulty of extracting what was wanted from the available mass. The file was so big it took up about 12 filing cabinet drawers, and so many papers had to be sorted each time there was a request for specific data, that considerable time elapsed before what was wanted could be found, or the fact that it was not there established.

A search was made for a better method of filing the data, and the Keysort System* was selected.

The System

The principle of the system is simple. Keysort cards, designed for the user's individual purpose, are delivered with round holes punched adjacent to the edges of the card (Figure II). A card is identified with a certain classification by notching out one or more holes to which certain meanings are assigned. A notched card is shown in Figure III.

To sort for cards of a certain classification, a steel tumbler or sorting needle is passed through the hole in the stack of cards representing the classification wanted. The sorting needle is then raised and the desired cards fall out because, since

★ A paper presented at the Annual Meeting of NACE in St. Louis, Mo., April 5-8, 1948.

* Corrosion Engineering Section, Development and Research Division, The International Nickel Co., Inc., New York, N. Y.

* McBee Company.

their holes are notched out, there is nothing to keep them on the needle. Figure IV shows the sorting operation.

Application of the System

After a conference with the Keysort representative a suitable card was designed. In order to avoid re-

C. O. 172 1M 4-48

CORROSION TEST DATA

FILE No._____
SPOOL No. _____
DATE_____

CORROSIVE MEDIA & CONC:

INDUSTRY: COMPANY:

PROCESS INVOLVED:

PROCESS UNIT:

LOCATION OF SPECIMENS:

TYPE OF TEST: DURATION OF TEST:

TEMPERATURE: AERATION:

GENERAL REMARKS: AGITATION:

	METAL	SPEC. CODE	CORROSION RATE MDD. EACH	CORROSION RATE MDD. AV.	CORROSION RATE IN./YR. AV.	PITTING DURING TEST—IN. SURFACE MAX.	PITTING DURING TEST—IN. SURFACE AV.	PITTING DURING TEST—IN. MAX. UNDER SPACER

Figure 1—Form on which corrosion test data are recorded.

typing the file it was decided to mount the existing typed forms on the Keysort cards. Kodak dry mounting tissue and a Kodak dry mounting press were used for this. This tissue gives a flat, permanent mount which does not make the card too thick and which will not dry out or discolor in time.

Cards were so designed that they might be sorted for: 1) all data on a specific chemical or mixture of

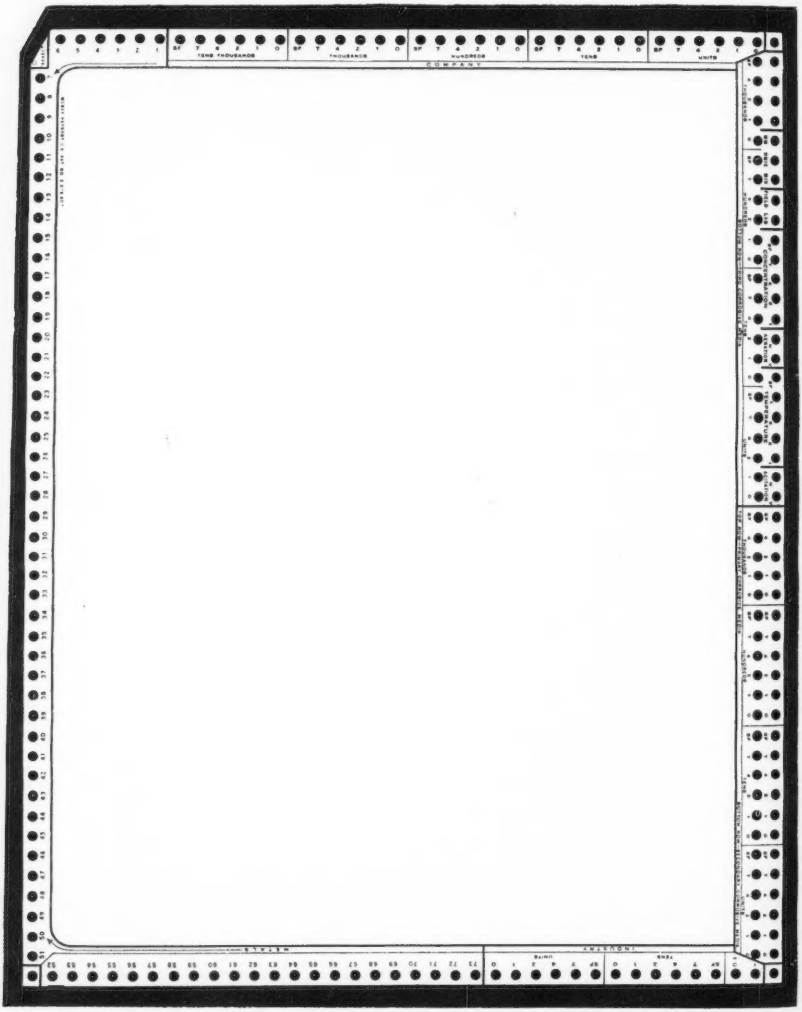


Figure 2—Keysort card.

chemicals for any test conditions; 2) all data on specific metals or alloys; 3) all tests made in a certain industry; or 4) all tests run for or by a certain company.

In most cases a numerical code was employed. Each field (units, tens, hundreds, etc.) is numbered 0-1-2-4-7-SF. Any number up to 9 may be recorded in each field by notching out two numbers. In the case of 1, 2, 4, or 7 the SF (single figure) is punched in addition to the number so that this number alone and not in combination will drop. That is, in sorting for 7, only the cards punched for 7 itself will drop and not the cards where 7 was used with 1 to make 8 or with 2 to make 9.

Using this numerical code, code numbers were assigned to every chemical, industry and company. Tables I and II show pages from

TABLE 1
Code for Chemicals.

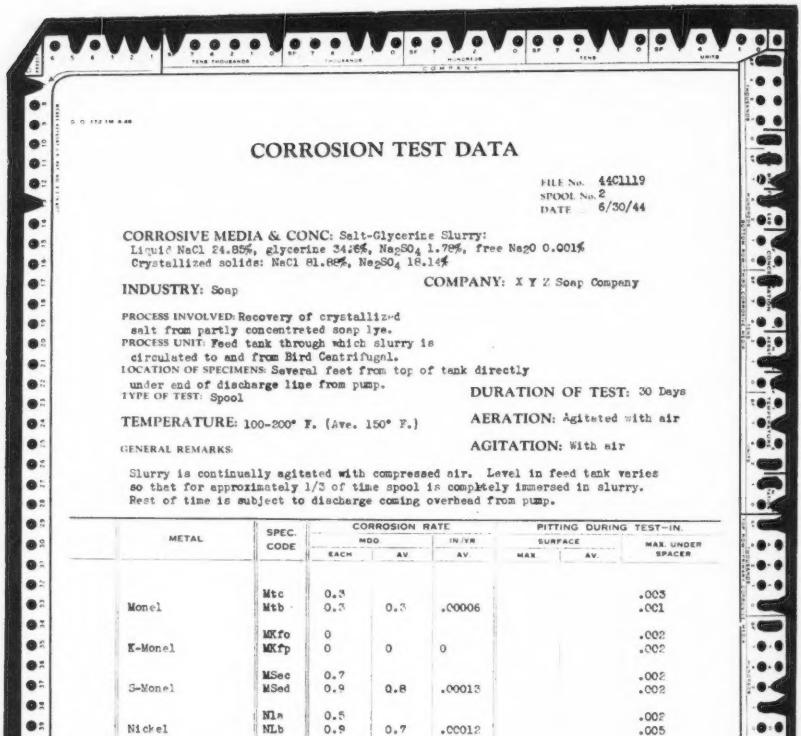
CHEMICAL	Code Number
Abietic Acid (see Fatty Acids)	166
Absorbine (see Pharmaceuticals)	309
Acetaldehyde	1
Acetamid	2
Acetic Acid	3
Acetic Acid plus Salt (see also Rubber Coagulating Bath)	542
Acetic Anhydride	4
Acetone	5
Acetylene Tetrachloride	6
Acetylsalicylic Acid (see Pharmaceuticals)	309
Aconitic Acid	8
Aging Solutions (see Acetic Acid)	3
Aktivin (see Chlorine)	117
Albone (see Hydrogen Peroxide)	211
Albumin	9
Alcohol:	
Amyl Alcohol	43
Butyl Alcohol	69
Ethyl Alcohol	158
Methyl Alcohol	263
Alkaloids (see Pharmaceuticals)	309
Alum:	
Aluminum Sulfate	17
Chrome Alum	119
Potassium Alum	326
Sodium Alum	378
Aluminum	10
Aluminum Chloride	11
Aluminum Fluoride	12
Aluminum Hydroxide	13
Aluminum Oxide	14
Aluminum Palmitate	15
Aluminum Stearate	16
Aluminum Sulfate	17
Amino-Acids	18
Aminoazobenzene	19
Ammonia (Anhydrous)	20
Ammonia Liquors	21
Ammonium Bicarbonate	23
Ammonium Bifluoride	24
Ammonium Carbonate	25
Ammonium Chlorate	26
Ammonium Chloride	27
Ammonium Citrate	28
Ammonium Fluoride	29
Ammonium Fluosilicate	30
Ammonium Hydroxide	31
Ammonium Nitrate	32
Ammonium Perchlorate (see Ammonium Chlorate)	26
Ammonium Persulfate (see Ammonium Sulfate)	36
Ammonium Phosphate	33
Ammonium Picrate	34
Ammonium Sulfamate	35
Ammonium Sulfate	36
Ammonium Sulfide	37
Ammonium Sulfite	38
Ammonium Tartrate	39
Ammonium Thiocyanate	40

TABLE 2
Code for Industries.

INDUSTRY	Code Number
Agriculture	1
Air Contitioning	2
Architerture	3
Automotive	4
Aviation	5
Brewing	6
Carbonated Beverages	7
Chemical Manufacture	8
Coal, Coke and Gas	9
Construction	10
Corn Products Refining	11
Dairy	12
Diesel	13
Distilled Liquors	14
Dry Cleaning	15
Electrical and Radio	16
Food Processing	17
Glass, Ceramics and Pottery	18
Heating	19
Household	20
Instruments	21
Jewelry	51
Laundry	22
Leather and Tanning	23
Lumber	24
Marine	25
Metal Works	26
Mining	27
Ordnance and War Materials	28
Paint, Varnish and Pigments	29
Petroleum	30
Pharmaceuticals	31
Photography	32
Pickling	33
Plastics and Synthetic Resins	34
Plating	35
Power	36
Printing	37
Pulp and Paper	38
Railroad	39
Rayon	40
Refrigeration	41
Research	42
Rubber	43
Sewage	44
Soap	45
Sugar	46
Textiles	47
Water Treatment	48

our code books of chemicals and industries.

The card in Figure III shows how the codes are applied. The main chemical here is sodium chloride and the other two chemicals concerned are glycerine and sodium sulfate. In the top row on the side of the card concerned with corrosive media the number for sodium chloride is notched out. The number is 389 so 0 is punched in the thousand field



CORROSION TEST DATA

FILE No. 44C1119
SPOOL No. 2
DATE 6/30/44

CORROSIVE MEDIA & CONC: Salt-Glycerine Slurry:
Liquid NaCl 24.85%, glycerine 34.6%, Na_2SO_4 1.7%, free Na_2O 0.001%
Crystallized solids: NaCl 81.86%, Na_2SO_4 18.14%

INDUSTRY: Soap

COMPANY: X Y Z Soap Company

PROCESS INVOLVED: Recovery of crystallized salt from partly concentrated soap lye.
PROCESS UNIT: Feed tank through which slurry is circulated to and from Bird Centrifugal.
LOCATION OF SPECIMENS: Several feet from top of tank directly under end of discharge line from pump.
TYPE OF TEST: Spool

DURATION OF TEST: 30 Days

TEMPERATURE: 100-200° F. (Ave. 150° F.)

AERATION: Agitated with air

AGITATION: With air

GENERAL REMARKS:

Slurry is continually agitated with compressed air. Level in feed tank varies so that for approximately 1/3 of time spool is completely immersed in slurry. Rest of time is subject to discharge coming overhead from pump.

METAL	SPEC. CODE	CORROSION RATE MDD EACH	MDD AV.	IN/YR AV.	PITTING DURING TEST—IN. SURFACE MAX.	SURFACE AV.	MAX. UNDER SPACER
	Mtc	0.3					.003
Monel	Mtb	0.3	0.3	.00006			.001
	MKfo	0					.002
K-Monel	MKfp	0	0	0			.002
	MSec	0.7					.002
S-Monel	MSed	0.9	0.8	.00013			.002
	Nla	0.5					.002
Nickel	NLb	0.9	0.7	.00012			.005
	NCoe	0.09					.001
Inconel	NClf	2.	1.1	.00019			.002
	Pqf	84			.005	.004	.004
Mild Steel	Pqg	88	86	.016	.004	.004	.003
	JAKr	0					
Ni-Resist	JAKs	0.3	0.3	.00007			

Figure 3—Keysort card with form mounted and punched for filing.

(0 + SF), 3 is punched in the hundreds (+1), 8 in the tens (7 + 1) and 9 in the units (+2). The solution was agitated so "Y" for "yes" is notched out over agitation, 4 (4 + SF) is punched in the temperature field to denote a temperature range of 100-200° F., "Y" for "yes" is punched out over aeration, and 2 (2 + SF) is notched out in the concentration field to cover the range in which 24 percent (the sodium chloride or main chemical concentration) appears. The solution is a mixture, so "M" is also notched out. This prevents the card from dropping when solutions of sodium chloride alone at the same concentration are wanted. The numbers for glycerine and sodium sulfate are notched out in the second row in the spaces for secondary and third corrosive media, respectively.

When sorting in the second row the cards do not drop free, because the numbers are recorded by making slots between the two rows of holes, instead of being notched to the edge of the cards. The cards fall about a quarter inch, however, so that they can be readily separated from the other cards.

The same coding system is used for industries and companies. This is illustrated in Figure 3 where the number 54 (4 + 1 in the tens, 4 + SF in the units) representing the soap industry is notched out in the industries field, and the number 3539 (0 + SF in the ten thousands, 2 + 1 in the thousands, 4 + 1 in the hundreds, 2 + 1 in the tens and 7 + 2 in the units) representing the XYZ Soap Co. is punched in the companies field.

Metals and alloys are recorded in a different manner. No numerical code is employed, but direct sorting is applied. That is, each hole in the field is numbered consecutively and represents a different metal or group of alloys. By using this system more than one number can be punched in the same field. This would be impossible if the previously described numerical code were used.

There were too many alloys to

TABLE 3
Code for Metals.

Group Number	ALLOYS
1	Monel
2	Modified Monel
3	Nickel
4	Modified Nickel
5	Inconel
6	Modified Inconel
7	Mild Steel
8	Low Alloy Steels (except Ni and Cr)
9	Iron (pure and wrought)
10	Nickel Steel
11	Nickel-Iron Alloys
12	Cast and Malleable Iron
13	Ni-Resist
14	Low Alloy Cast Iron
15	High Silicon Cast Iron
16	Chromium Steel, 4-10%
17	Chromium Stainless Steel
18	18-8 Stainless Steel (including Cb and Ti modifications)
19	18-8 Stainless with Mo or MoCb
20	Modified 18-8 Stainless
21	High Cr-Ni Stainless Steel
22	Ni-Cr-Fe Alloys
23	Ni-Cu Alloys (except Monel)
24	Cu-Ni Alloys
25	Hastelloy A
26	Hastelloy B
27	Hastelloy C
28	Hastelloy D
29	Illium
30	Hard-Facing Alloys
31	Ni-Cr Alloys
32	Cast Tin Bronze
33	Rolled Tin Bronze
34	Bronzes with no or little Sn
35	Cast Brass
36	Rolled Brass
37	Ni-Modified Brass or Bronze
38	Aluminum Bronze
39	Silicon Bronze
40	Nickel Silver
41	Copper and Copper Alloys
42	Lead and Lead Alloys
43	Aluminum and Aluminum Alloys
44	Silver and Silver Alloys
45	Tantalum
46	Platinum Group Metals
47	Gold
48	Magnesium and Mg Alloys
49	Tin
50	Zinc
51	Other Metals
52	Non-Metallic Materials

give each alloy a separate number, so they were classified in groups by composition. Table 3 is a partial list of the alloy groups. Then, to simplify things, all the alloys for which there were data were listed in alphabetical order with their nominal compositions and the numbers of the groups to which they belong. Table 4 gives extracts from the alloy list.

Note in Figure 3 that on the side of the card for metals, number 1 is notched out for Monel, number 2 for modified Monels ("S" and "K"), number 3 for nickel, number 5 for Inconel, number 7 for mild steel and number 13 for Ni-Resist.

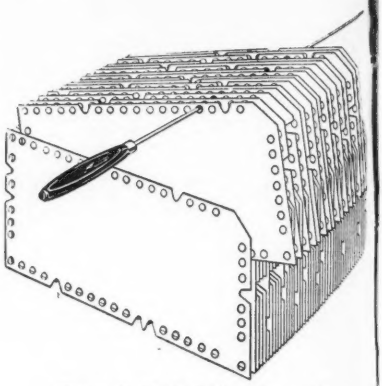


Figure 4—Method of sorting cards.

TABLE 4

Code Numbers for Alloys.

ALLOY	Group Number
Acid Resistant Bronze	32
Admiralty Metal (29 Zn, 70 Cu, 1 Sn)	36
Adnic (70 Cu, 29 Ni, 1 Sn)	24
Advance (55 Cu, 45 Ni)	24
Albro	32
Alcumite (88 Cu, 8 Al, 3 Fe, 1 Ni)	38
Alcunic (80 Cu, 1 Ni, 2 Al, 17 Zn)	37
Allegheny (.12 max. C, .5 max. Mn, 17-20 Cr, 7-10 Ni)	18
Aloyco 20	22
Alumel (94 Ni, 1 Si, 22 Al, 0.5 Fe, 2.5 Mn)	4
Aluminum	43
Aluminum 2S (1% max. impurities)	43
Aluminum 3S (98.75 Al, 1.25 Mn)	43
Aluminum 52S (2.5 Mg, 0.25 Cr, bal. Al)	43
Ambrac (74.5 Cu, 20 Ni, 5 Zn, 0.5 Mn)	40
Ambraloy (95 Cu, 5 Al)	38
Antimonial Lead	42
Armco Iron (.012 C, .017 Mn, .005 P, .025 S)	9
Barronia Metal (83 Cu, 9.5 Pb, 4 Sn, bal. Zn)	32
Brightray (80 Ni, 20 Cr)	31
Bronze (85 Cu, % Sn, 5 Zn, 5 Pb)	32
Carbon Steel	7
Cadmium	51
Cast Iron	12
Causul Metal (15 Ni, Cu, Cr, C, bal. Fe)	13
Chemical Lead	42
Chlorimet	22
Chromel (80 Ni, 20 Cr)	31
Chromium	51
Chromium Cast Iron (30% Cr)	57
Chromium-Iron Alloys (4-10% Cr)	16
Chromium Stainless Steel (11 and more % Cr)	17
Cr-Mn Steel	8
Cr-Mo Steel	8
18-8 Stainless	18
18-8-Cb	18
18-8-Mo	19
18-8-Ag	20
18-8-Ti	18
25-12 Cr-Ni Stainless	21
25-20 Cr-Ni Stainless	21
Chromium Plate	56
Cobalt	51
Colmonoy	30
Commercial Bronze	34
Copper Steel	8
Corronite	55
Corrosion (13.5-14.5 Si, .8-1.0 C)	15

The cards have the capacity for 6,999 chemicals, 99,999 companies, 199 industries and 73 alloy groups.

Codes

Inasmuch as the codes are continually increasing as tests are made for new companies, in new chemicals and on new alloys, some means had to be found for recording the codes so that they could be added to continually and kept in alphabetical order without constant re-typing.

For this purpose Acme Rotating Frame Books * are used. In these each entry is made on a strip of cardboard, and when an addition to the code must be made, the strips are pushed aside and the new one inserted in the proper place.

Advantages

The Keysort system has been better than anticipated. A great

* Acme Visible Records, Inc.

deal more space was saved than expected because not only was it possible to combine four files into one, but all cross-reference sheets were eliminated. The file now occupies four drawers instead of 12.

In addition, a great deal of time required for looking up data is saved. The longest searches now take only 2 to 2½ hours instead of 28. In fact, specific data usually can be located so rapidly that an engineer can often answer long distance requests for information while still on the telephone.

Thus, the whole section can work more rapidly and efficiently, the delays occasioned by waiting for data to be found having been eliminated.

Bearing Corrosion in Turbo-Generators*

By J. A. Ten Broeke*

INTRODUCTION

IN THE locating of bearing troubles on turbo-generators, it is useful to have an overall knowledge of the possible electrical, mechanical and chemical causes.

The maintenance of the lubricating system of a turbo-alternator, which includes the generator and exciter bearings is the responsibility of the mechanical maintenance engineer. If any pitting or etching of journals and bearings is found, the cause is invariably put down to acidity of the turbine lubricating oil. This thought was particularly prevalent during the period immediately following World War I.

Very little has been published on the causes and effects of stray currents,[1] and most of the technical information is of German origin.[2] The papers and technical data have been produced for the assistance of designers of electrical machinery, and therefore, they are not readily available to the operating engineer.

The build up of electrostatic charges through the rotor of the electrical machine[3] has been covered to some extent and is readily understood, but as far as the author is aware, nothing has been published on the subject of electrostatic charges being caused by the brushing effect of steam on the turbine blading. The following examples of the effects of stray currents and electrostatic charges should be of interest to all concerned with the efficient running of generating plants.

Stray Currents

Case 1.[4] The machine is a 3500 kw., 3000 rpm, 6600 volts, 3-phase turbo-generator. After many years of satisfactory running it developed a rotor earth fault, but as it was not convenient to take it out of service immediately, it was run for some weeks until repairs could be made. During the few days before coming out of service, heavy vibration was observed. This point is of importance because it indicated the probability of a second earth fault having developed. When the machine was dismantled, it was found that the bearings were damaged, the journals being pitted and scored over the entire length and about half the circumference, the bearings being severely wiped.

The rotor was removed, the journals turned, the bearings re-metalled, and the machine put back into service. After 3½ months, a quantity of finely divided metal was found in the oil filter, and the machine was again opened up for inspection. This time deep grooves were found in the journals in bands (Figure 1), and a

★ A paper presented at the Annual Meeting of NACE in St. Louis, Mo., April 5-8, 1948.

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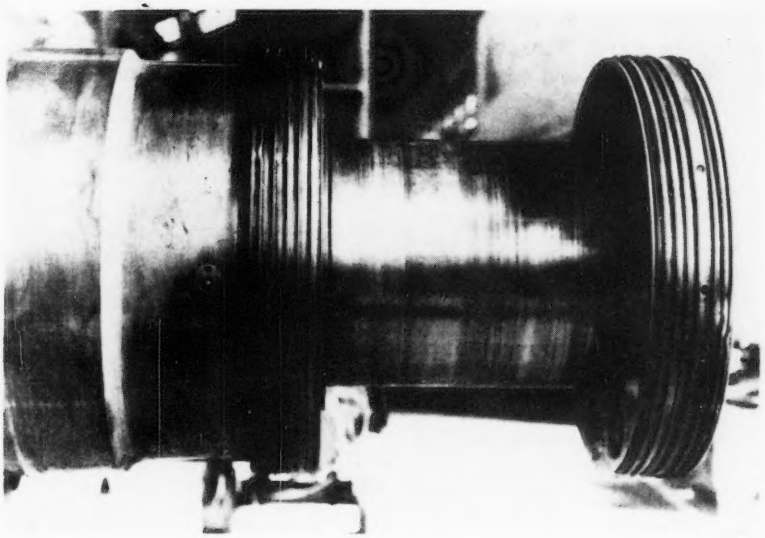

Figure 1

number of scars slightly oblique to a plane at right angles to the center line of the shaft were found on the bearings (Figure 2). These scars were about 1½ to 2 inches long and about ⅛ inch wide, and were found to contain particles of steel, apparently from the journal, which were embedded in the white metal and were evidently the cause of the grooves in the journal. A curious feature of these scars was that parts of them were in oil grooves and were, therefore, not in contact with the journal.

A thorough investigation of the machine was made, and at first no cause could be found. The damage appeared to be caused by electric currents, but the usual symptoms of this, pitting of the worm drives of tachometer and governor and deterioration of the oil were absent. The insulation of the excitation system was tested and found to be perfect. No mechanical cause was found, the bearings having been metalled in a satisfactory manner, and the possibility of foreign matter in the lubricating oil system being ruled out by the other bearings of the machine being in perfect condition.

It was then discovered that the housing of one of the damaged bearings, No. 4, was strongly magnetized, and investigation showed that the entire frame of the machine was magnetized at the exciter end. The machine was assembled and run to enable shaft voltages to be taken at the points marked A, B and C in Figure 3, with the following results: A — B: — 125 millivolts; A — C: + 172 millivolts; B — C: + 296.

These, combined with the evidence of magnetization already de-

scribed, indicated flux paths as shown by the dotted loops in Figure 3, and these would end to produce currents in the paths of the chain-dotted loops, one through the frame of the machine and through the shaft between bearings 3 and 4, and the other circulating round journal and bearing in No. 4 bearing. Circulating currents would, of course, tend to flow in each small length of No. 4 bearing but as the resistance of the oil film is included twice in each circuit, the current might be expected to be greatest at the ends, where the potential difference would be a maximum. The effect of these currents would be to damage No. 4 bearing mainly near its ends and No. 3 bearing more or less uniformly, and this hypothesis is confirmed by the actual results, and shown in Figure 2.

The next problem was to demagnetize the machine. The first attempt, with a coil of some 6000 ampere-turns of 50 cycle ac, applied to various parts of the dismantled machine, met with little success, and a further application to a coil of 1200 ampere-turns wound in the air space between stator laminations and outer frame was completely unsuccessful. It was thought that the eddy currents produced by the 50-cycle flux might be so great as to prevent effective demagnetization, so a change was made to slowly reversed dc, the current being slightly reduced at each reversal, starting with a value calculated to be somewhat greater than that corresponding to the coercive force for the magnetic path concerned, and finishing with a very small fraction of this figure.

This method ultimately proved

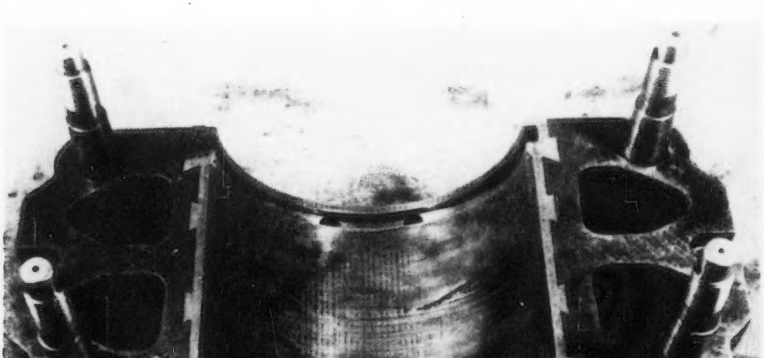

Figure 2

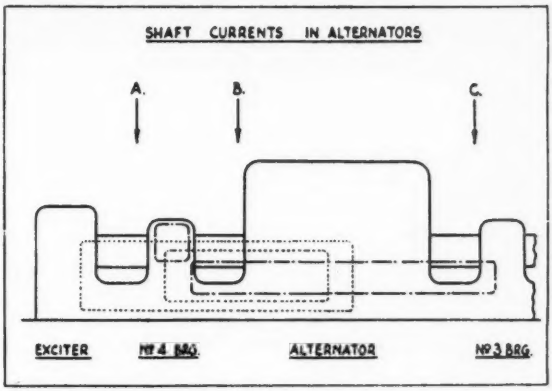

Figure 3

completely successful when applied to a series of coils so arranged as to link every possible magnetic path with the machine assembled, so as to avoid the considerable air gaps that would be inevitable with the machine in pieces. The application of this method was carried much further than the 50-cycle method, so it is not possible to say what success might have been achieved with the latter had it been pursued.

Final figures of shaft voltages were: A — B — 46 millivolts; A — C — 12 millivolts; B — C + 33 millivolts.

It is presumed that the original cause of the magnetization was a double earth fault in the rotor causing unequal ampere-turns in its two coils and a consequent "spillage" of flux axially along the shaft, through the bearings—particularly No. 4—and the alternator frame. No. 4 bearing housing was not insulated from the frame, but even if it had been, the current circulating within it would still have occurred and the insulation would have been no safeguard, except to prevent the currents circulating between Nos. 3 and 4 bearings. Similarly, the fitting of a shaft earthing brush would be of little avail.

The freedom from deterioration of the lubricating oil was surprising, but the suppliers of the oil have stated that currents through a film of oil may or may not cause acidification or sludging, depending very largely on the amount of moisture present.

Electrostatic Charges

Case 2. It might be of interest to note that this case came to light when the author showed the station superintendent the photograph and details of Case 1.

The machine is a 10,000 kw., 3000 rpm, 6600 volts, 3-phase turbo-generator, steam conditions 200 psi, 700/750° F., installed 1937. During a week-end inspection in 1946, it was seen that the worm (Figure 4), and governor wormwheel (Figure 5), were badly worn and replacement parts were ordered. The wear was put down to mechanical failure. Subsequently, the author called and, as

previously stated, a new angle was followed to check the cause of the failure.

The manufacturers of the turbine confirmed from their experience that the wear and pitting of the worm and wormwheel were due to electrostatic charges caused by the turbine *Not* the alternator.

Case 3. The machine in this case is a 30,000 kw., 3000 rpm, set, steam conditions 600 psi, 800/850° F.

A complaint was made that the oil was oxidizing and a gummy deposit was forming on the shaft and likely to impede the action of the over-speed trip bolt located in the shaft between "C" and "D."

The matter was investigated and a number of interesting points were noted.

The shaft (Figure 6) was "blued" between "A" and "B," the color being dark at "A," and lightening gradually along the shaft towards "B." This indicated tempering or excessive heating of the shaft but there was no confirmation of any high temperature as the bearing oil return from the journal adjacent to "A" was well below 140° F.

The oxidized oil deposit was localized on the shaft between "C" and "D," and no signs of deposits occurred elsewhere on bearings or journals.

Further questioning revealed that the original wormwheel had failed and had been replaced. Shaft currents had been suspected but no recordings of any current could be taken on a millivoltmeter.

The reported failure of the wormwheel gave the pointer to the possible causes of the "blueing" and the

Figure 4

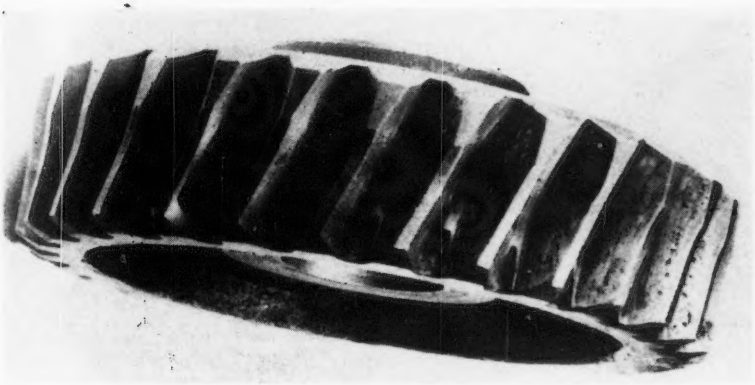

Figure 5

localized nature of the oxidized oil deposit.

It is a well known fact that not only does an electrical discharge cause the formation of ozone but also that ozone is a strong oxidizing agent. The deductions drawn from the known facts were:

(1) As there was no oil film on the shaft between the points "A" and "B," there was no protection against the ozone, and "skin" oxidation of the steel took place.

(2) The oil fed to lubricate the worm and wormwheel tends to throw forward between "C" and "D"; this oil is in a fine film on the shaft and also in mist form inside the housing and in an ideal condition for oxidation to take place.

While the oil film on the shaft would remain as a deposit, the oxidized oil mist would fall in the main oil flow leading into the settling tank. This was shown by the periodic separation of an oxidized oil product in the bowl of the centrifugal oil separator which is running on the continuous by-pass system taking the dirty oil from the bottom of the settling tank.

Confirmation has been given from two other sources that similar occurrences had been experienced and proved to be due to electrostatic charges caused by the turbine end.

Case 4.[5] This turbo-generator had been in service several years before an inspection revealed a badly worn thrust bearing.

A new thrust bearing was fitted and remained serviceable for less than two weeks; trial of another bearing was no better.

The cause of the trouble was finally traced by the use of an oscilloscope; the oscillograph showing the continual build-up and discharge of electrostatic charges. Further trouble was stopped by fitting a brush and grounding the turbine shaft.

In quest for full information on the subject of electrostatic charges, the author finds that very little detail appears to be available for general release. Several facts have come

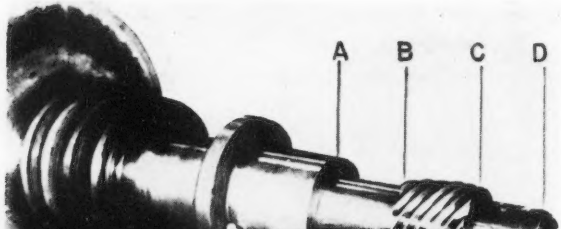

Figure 6

to light which might explain this absence of data.

General experience has shown that it is quite impossible to foresee when or under what steam and load conditions the formation of these charges will occur. Suitable instruments are very seldom available for test; it has been proved that a high resistance voltmeter is necessary to measure the tone current. If electrostatic charges are suspected but no recording of current can be made then it is necessary to fit an oscilloscope in order to take recordings over an indefinite period; this latter method has been found to be the only satisfactory method of checking for the definite, if only periodic, presence of electrostatic charges.

In confirmation of the foregoing "case histories" and statements, it should be remembered that several of the leading turbine manufacturers in Great Britain have standardized the use of earthing brushes for grounding the turbine shaft. This fitting of a brush is not costly and compares more than favorably with the likely cost of research work to trace all the possible causes and combination of conditions which must exist to allow the formation and build-up of electrostatic charges.

References

1. P. L. Alger and H. W. Samson, Shaft Currents in Electric Machines. General Electric Review, **27**, No. 3, 188-198, (1924) March.
2. P. L. Alger and H. W. Samson, Shaft Currents in Electric Machines, General Electric Review, **27**, No. 3, 188-198, (1924) March.
3. P. L. Alger and H. W. Samson, Shaft Currents in Electric Machines, General Electric Review, **27**, No. 3, 189-190, (1924) March.
4. This Case history was supplied in full detail to the author of this Paper by an undertaking which prefers to remain anonymous. The author's thanks are recorded herewith.
5. Details on Case 4 are given in discussion.

DISCUSSION

*By E. F. Dissmeyer**

Mr. Ten Broeke presents descriptions of interesting cases where electrostatic charges have contributed to the failure of turbine bearings, gears, etc. Undoubtedly there have been many unexplained cases of mechanical failure which may have been caused by electrostatic phenomena. This is illustrated by the following case of motor bearing trouble which was experienced by one of our client companies.

A number of bearing failures were experienced on motors driving exhausters used in a generating station powdered fuel installation. After a comparatively short period of operation it would be found that the bearing oil would become discolored and sludging would occur. Unless the oil was replaced frequently the motor bearings would fail after a month or two of operation. For some time the cause of this bearing trouble could not be determined. During one of the frequent inspections of the motor a maintenance man noticed that an electrostatic spark occasionally occurred between the motor shaft and its bearing. Apparently the operation of the exhauster in coal-laden air was collecting sufficient static so as to build up a voltage sufficient to cause a spark between the shaft and the bearing.

A suitable brush was installed which would provide a short circuit across the bearing oil films. There has been no further difficulty with the motor bearings since the installation of these brushes.

AUTHOR'S REPLY

The author wishes to thank Mr. Dissmeyer for his written discussion on the paper and his report on the failure of motor bearings, due to electrostatic charges.

Further information would be appreciated as to size of motor, electrical details, speed, method of drive to the exhauster; size of grounding brush, material and method of mounting.

The author also welcomes and appreciates the contributions to the oral discussion by Messrs. G. A. Mills, E. A. Rudolph, and others.

The following extract from a letter written by the Chief Engineer, Turbine Department of the Manufacturers of the turbo-alternator mentioned in Case 4 should be of assistance in answering the various queries raised as to the possible presence of electrostatic charges and the effects of these charges on turbine bearing and gears.

"The circumstances at ——— outlined by Mr. Ten Broeke are substantially correct. This machine is

* The Commonwealth & Southern Corp., Jackson, Miss.

of our standard two-cylinder construction with flexible couplings between each pair of rotors, and the alternator rotor is located axially by Mitchell type thrust pads fitted at each end of the inboard alternator bearing. After several years' satisfactory operation, rapid wear commenced on these thrust pads, to such an extent that they had to be replaced every week-end, and no suitable explanation was forthcoming for this rapid wear. All normal mechanical checks were taken, but nothing could be found which accounted for the trouble, and as a last resort it was considered that it might be associated with similar trouble we had had with rapid wear of phosphor bronze worm wheels driven by a steel worm mounted on the steam end of the H.P. rotor, which trouble had been definitely traced to electrostatic charges building up on the turbine rotors and discharging to earth as soon as sufficiently high potential was reached through the bronze worm driving the governor and the governor levers and so to earth.

"In view of the metallic connection between all rotors it was thought that possibly these electrostatic charges were attaining their maximum value at the alternator rotor and discharging to earth through the thrust pads mentioned. This was in fact substantiated by electrical measurements, and in view of the difficulty of fitting an earthing brush to the alternator rotor itself owing to the high surface speed glazing the brush, the expedient was adopted of fitting a carbon brush on the steam end of the H.P. turbine rotor and connecting this to earth. Notwithstanding the fact that the circumstances appear almost incredible, as soon as this brush was fitted the wear on the thrust pads disappeared, and no trouble has been encountered since.

"We have on many occasions experienced these electrostatic charges on the turbine rotors, and as stated above, they have, where existing, caused serious trouble due to rapid wear of the bronze gearwheel referred to, and the fitting of a similar carbon brush has eliminated this wear to such an extent that the carbon brush is now practically a standard fitment on all our large machines.

". . . The evidence regarding the electrostatic charges on steam rotors is quite definite as we have actually measured these on a number of occasions, and our attention was first drawn to them by one of our outside staff reporting that sparks were observed when an oil can was brought into close proximity to the governor gear mechanisms. We believe that it has been previously established that the charges are produced by the friction produced between the water drops entrained in the steam and the high speed parts of the turbine rotors; we understand that this has on more than one occasion been referred to in the technical literature on steam turbines, although we are unable to give any precise reference to this.

"The steam conditions under which the machines mentioned above operate are 650 psi. and 800/850° F. total temperature.

"The above are the detailed circumstances referred to generally by Mr. Ten Broeke."

Formulation of Corrosion Resistant Paint*

By John W. Nee*

THIS SUBJECT was selected as the basis for an article because of the increasing importance of organic surface coatings in the field of engineering as a means of combating corrosion. The need of corrosion-resistant finishes to protect installations of chemical and refining plants is more evident when we consider the fact that losses in the refining industry alone are equivalent to approximately one cent per gallon of gasoline produced.[1,2] It is even more evident that paint in its various complex forms has now entered the realm of engineering when we consider that Joseph Mattiello, a leader in the paint manufacturing industry, was the guest lecturer before the American Society of Testing Materials at its annual National Convention in Buffalo, New York, in 1945. Not only was this a signal honor but it served notice to the entire paint industry that they had become of age as a scientifically regulated industry instead of a craft or art as paint making had been considered for so many years. Dr. Mattiello's address was entitled "Paint, a Tool for the Engineer." It is with these thoughts in mind that we attempt to evaluate some of the things the paint chemist and his counterpart in the raw material field have done to produce better surface coatings for corrosion resistance.

Since the raw materials available to the formulator of paint and varnish are so many and so varied it would be impossible to touch on more than a few of the most important in the field of chemical resistance. For the purpose of this discussion we have selected what we consider five of the outstanding materials available to the paint chemist in designing finishes of extreme corrosion resistance. They are the following: 1. Phenolic Resins (a. Oil Soluble and b. Thermosetting); 2. Courmarone-Indene Resins; 3. Vinyl Resins; 4. Chlorinated Rubber; 5. Specialty Resins (Synthetic Rubber Derivatives). And to this group of resins we wish to add a few of the pigments used in formulating primers for exposure *under* suitable top coats in corrosive areas. Our selection is restricted, in this instance, to pigments for primers only, for two reasons:

(1) A good prime coat is a prerequisite of a good finishing system.

(2) Colors in top coats may vary to suit the fancy of the consumer, but the number of pigments available for good inhibiting properties on primers is limited and a more complete report can

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be written on this smaller number of important pigments.

It would be appropriate at this point to explain roughly the terminology of the paint industry in regard to the general composition of surface coatings.

Varnishes are composed of one or more oil soluble resins, one or more drying oils (Tung, soya, linseed, dehydrated castor and others) and a volatile portion generally known as the thinner or reducer.

Pigmented coatings (primers, paints, enamels) usually consist of two basic parts:

(1) Pigment. The active pigments that add color and opaqueness to the film, and in some materials, inert pigments used as extenders, to increase adhesion, adjust and control viscosity, aid in application and other special purposes.

(2) Vehicle. The solid vehicle composed of oils, resins, plasticizers, which does not evaporate and forms the film which binds the pigment to the substrata coats and acts as a barrier to the penetration of corrosive agents that would attack, corrode and destroy the substrata. The volatile portion of the vehicle is used to keep the film fluid and allow adequate application and flow until it evaporates and the film is formed.

Since the volatile portion is not of interest to us in the activity of the completed film we do not plan to examine the various volatile materials that are used but rather to discuss the resinous bases from which coatings are formulated.

The Phenolic Resins

Leo Baekeland perfected the first of the phenolic resins in 1909. From this start many investigators took over and years of work were applied to the improvement of his initial efforts. It was not until 1928 that the first oil soluble phenolic resin was perfected. The resins of this type are reaction products of phenol (of various types) and aldehydes (usually formaldehyde).

Actually, the introduction of the phenolic resins into the varnish industry added impetus to the trend away from a "father to son" art and the introduction of scientific methods of varnish making. It is of interest to note that the initial oil soluble phenolic resins found a place in the marine field and have held a prominent place in this field ever since. Originally they were considered for use only with the hard drying tung oil, with linseed and other soft oils as added components to reduce cost of the finished product. With the coming of the war, and the loss of tung oil imports from China, the linseed and dehydrated castor oils were used and found in general to yield excellent results, comparable with those of tung oil formulations, and in some cases even better. The 100 percent phenolic resins, prior to the war were used principally in industrial maintenance work. Their excellent durability and resistance to moisture and abrasion were responsible for their use in primers and coatings on canal locks and dams, bridges, oil storage tanks, steel

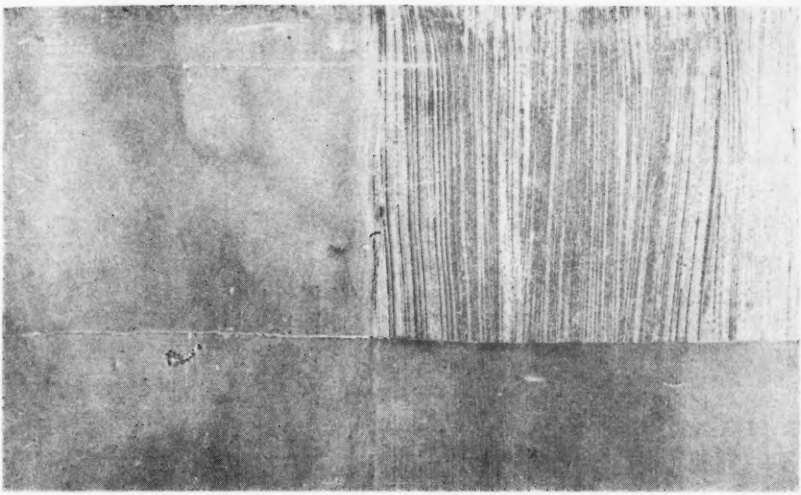


Figure 1—Panel coated with two blue lead primers and two-thirds coated with a top coat. On the left side a blue lead primer made from blue lead and a phenolic resin varnish was used. Right side, a blue lead primer made from blue lead and raw linseed oil. Coatings were exposd on steel for six months in Florida. Note rusting on panel in upper right side. (Panel-Bakelite Corp.)

freight cars and structural steel. The same properties made them a must for yachts and ships, and as a base for marine coatings of all sorts. They have excellent chemical properties when compared to the old type of ester gum and fossil resin varnishes, but do not have as high a chemical resistance as vinyl resins and chlorinated rubber. Phenolic resins definitely have a prominent place in today's surface coating, however, even if they are not used to coat acid storage tanks and other highly corrosive areas, they are without a peer for the types of application mentioned where limited chemical resistance combined with outstanding durability is concerned.

The 100 percent phenolics tend to provide excellent leafing in aluminum paints, but do not find extensive usage in white paints, due to strong tendency to yellow. Phenolic resins normally require solvents stronger than aliphatic spirits to keep them in solution, and exhibit strong tendencies to develop surface skin. Proper formulation can ordinarily reduce these disadvantages. One complaint about their use has been the lamination of subsequent paint coats, particularly after the phenolic coating has aged for some time. Correct choice of solvents in the new paint being applied has reduced this tendency, as has proper selection of oil and resin composition.

The use of oil soluble 100 percent phenolic resins in industrial maintenance is exhibited best in Figure 1, which shows the effect of using a phenolic varnish as the vehicle in a blue lead primer as against the use of raw linseed oil. This panel was exposed for six months in Florida.

Note the rusting on the half of the panel that contained linseed oil as a vehicle, while the other portion of the panel is perfect. The balance of the panel above the primer is coated with a standard phenolic resin base top coat. It is interesting to those engaged in operations using magnesium alloys that these resins can be made into varnishes for vehicles in primers with exceptional adhesion to such metals as Dow "J."

Another type of phenolic resin is the thermosetting resins, which are usually liquids that cure or harden with heating or baking. These resins are usually modified with oils, plasticizers or other resins and when properly applied and cured under enough heat (one hour at 350° F.) are practically insoluble and have a hardness approaching glass. They can, however, be formulated into coatings which are quite flexible. These have exceptional properties but do not lend themselves to field application, so we will not dwell on them in detail in this paper.

The second in our group of selected resins is the Coumarone-Indene resins, manufactured as a by-product of bituminous coal coking. The Coumarone-Indene type of resins has been known since about 1890 when Coumarone and Indene were first isolated from coal tar by fractionation. These resins as a group are very closely related to the Styrene-cyclo pentadiene combinations.

These resins are chemically inert and have very high resistance to acids, alkalis, and other corrosive chemicals. They are oil soluble and can be combined with most of the vegetable oils used in modern varnish making. The resins in this group do not normally combine well with dehydrated castor oil, but in most other oils they have a distinct retarding effect on the gelation of the oils in temperatures up to 600° F. When combined with oils in varnishes they produce excellent films of good gloss and clarity but poor in color. The chemical resistance of these varnishes is usually very good, particularly to alkali, and is dependent largely on how much and what type of oil is used, since the resin itself is not easily attacked.

The Coumarone-Indene resins are used largely in floor finishes in the trade, but in corrosion resistance they excel as aluminum vehicles. In the oil refineries the amount of Coumarone-Indene resins used in aluminum finishes for tanks is very great. The leafing and brilliance of aluminum in these coal tar derivative bases is excellent, both in storage in the container and when applied to the surface to be painted. These resins are non-toxic and have been used as vehicles for lining food cans for many years. Other uses are bases for structural steel primers, insulating varnishes, in marine hull coatings, and in general as good prime coat vehicles when properly formulated. They do not readily oxidize and unless used with some oxidizable material (such as a drying oil), which admittedly will reduce their resistance to chemicals, they remain soluble in aromatic solvents. This is a disadvantage in some cases where high solvent resistance is required, and low oil content is desirable.

We can proceed to the resins under the vinyl grouping, which are gen-

erally all co-polymers of vinyl acetate-vinyl chloride. The desirability of manufacturing co-polymers is indicated by the high resistance—low solvency of poly vinyl chloride, and the relatively low resistance—high solvency of poly vinyl acetate. The normal concentration of chloride-acetate in the co-polymer is 87-13, although variations of this are made for specialized products. The 87-13 ratio yields a desirable balance between chemical resistance, solubility and film toughness. The reaction between the vinyl chloride, a gas, and vinyl acetate, a low boiling liquid is a joint co-polymerization to produce the white powdery resin used in industry today.[4] These resins may be made with chloride-acetate ratios varying from 62-38 to 95-5. They are soluble only in the ketones, esters, cyclic ketones, nitroparaffins and other strong solvents, but once dissolved may be diluted to as much as 50-50 blends of strong solvents and aromatic hydrocarbons. It is possible also to make solutions with resin solids as high as 20 percent in equal part blends of ketones and aromatic hydrocarbons. The vinyl co-polymers will blend with many types of materials for the purpose of plasticizing them. Among this group are many chemical plasticizers, i.e., chlorinated di phenyls, chlorinated paraffins, and many others. Several resins of the Coumarone-Indene class are also compatible and can be used in this group.

Vinyl resins were used for years solely in baking finishes because the adhesion of air dried coatings was considered poor. On baking, special precautions had to be taken to prevent the breakdown of the resin with a resultant release of hydrochloric acid, which would disintegrate the film and turn it black. These resins can be stabilized against this reaction by use of basic carbonate of white lead, calcium ethyl aceto-acetate, Strontium Napthanate and several others. Today's vinyl co-polymers have been modified in many cases for better adhesion of air dried films (such modification may be use of a di basic acid in the co-polymerization process to extent of 0.5 percent, for instance, maleic anhydride) and during the war years the air dried vinyl composition came into its own. It was surprising to find the vinyls being used on large tanks, for coating concrete, on marine hulls and superstructure under the most trying conditions and standing up admirably well.

Vinyls have high acid resistance, are not attacked by alkali, resist greases, oils, and aliphatic solvents, and can be used under water for extremely long periods of time. Actual experience has recorded the use of vinyl coated derail signs on a railroad siding in a sulphuric acid pumping station for over four years with no failure. Panels exposed in Florida show no chalk for 30 weeks, and in black vinyl enamels exposure experience in Florida shows perfect results in four years with only slight loss of gloss. The use of these resins is becoming more widespread for industrial maintenance especially in areas of high corrosion. The disadvantages of these coatings are the high solvency solvents which often tend to swell and lift old paint coats in repaint work unless some barrier coat is used between the old paint and new vinyl coating. The fact is

that normal vinyl materials are of necessity low in solids because of high viscosity in solution; thus dried films are thin and multiple coats are usually required to build film thickness. These obstacles are being partially overcome by the use of a new vinyl resin recently introduced which will allow blending with alkyd resins and other oil base materials to impart vinyl properties to them and likewise increase the solids at the same time. This is another example of the advances made in this industry in the last decade which result in better products for the engineer to employ in his fight against corrosion of all types.

Another advancement during the last few years was the development by the Bakelite Corporation under contract to the U. S. Navy of the new concept of priming materials known as "Wash Primer." Our industry now has a primer which will adhere to hard-to-coat metals, has unusual properties of resistance, and considerably improves the performance of practically all coatings applied over it. This "wash primer" is based on polyvinyl butyral, a reaction product of a vinyl acetate polymer (with 97 percent of the acetate groups removed) and butyraldehyde, until a product with 7 percent hydroxyl content is obtained.

This resin is dissolved in alcohols and a water insoluble zinc chromate (basic) pigment is incorporated and by action of dilute phosphoric acid an insoluble film is produced with outstanding adhesion qualities. One disadvantage to the use of this primer is its tendency to gelation if not used within 8-12 hours after mixing the component parts on the job. Package storage before blending at time of use is good, so it can be made and shipped and stored for periods up to 90 days without loss of its excellent properties. One outstanding advantage is its ability to dry in 3-5 minutes sufficiently hard to prevent pickup of sand from sandblasting operations. This enables the industrial maintenance operator to sandblast and follow immediately behind the sandblasting operation with an excellent protective coat to prevent re-rusting of the sandblasted area. In operations like this, any sand that blows across the newly sprayed area does not adhere and can be brushed up before application of secondary coats.

Chlorinated rubber is another of the very useful tools of the paint formulator. This resin has a number of desirable properties; it is a clear, odorless, tasteless, non-toxic and non-inflammable material with very high resistance properties.

Chlorinated rubber was first introduced into this country from Germany about 1934. It has been improved many ways in the last 15 years and today represents a very remarkable working tool for the engineer to use for corrosion resistance. Chlorinated rubber has a white powdery appearance in the initial state, and is soluble in aromatic solvents, hydrogenated petroleum solvents, esters and ketones. By the proper seleection of plasticizers, either chemical (such as chlorinated di phenyls) or of oil base (bodied oils, alkyd resins, etc.), films can be obtained that will dry in rapid time, are flexible, tough and very resistant to alkali, acids, chemical attack, and

will yield extremely high durability to atmospheric conditions.

Chlorinated rubber consists of 35 percent rubber and 65 percent chlorine, so that in each pound of chlorinated rubber we have one-third of a pound of natural rubber and two-thirds of a pound of chlorine. This most versatile resin, when dissolved in a solvent and properly plasticized can be used to speed up production in the product finishing field where its rapid air dry or low temperature bake makes it very economical material to use. It can be used to formulate paints for concrete floors or walls, for protection and decoration of asbestos or cement base siding, for swimming pools, for chlorination pits and many other places where the alkali from the concrete would quickly destroy an oil base film. These finishes can be designed to work on wood, metal, concrete and other surfaces; they will yield finishes for oil field equipment, for structural steel, for bridges, or railway equipment. In recent years great strides have been made in adopting chlorinated rubber to marine use. Actually, it is now possible to add to a Maritime Commission specification marine primer, up to 30 percent of chlorinated rubber on the weight of the vehicle solids, and add years to the under-water resistance of this material. Chlorinated rubber is now being used extensively wherever the need for resistance to corrosive chemicals, corrosive atmospheres, fresh water, salt water, and the general over-all attack of sun and air is required.

Chlorinated rubber has one deficiency which the skillful formulator can avoid, it has a tendency to be softened in vegetable oils. Many means are available to combat this deficit, and also the tendency toward resolvency in mild solvents. Like most organic finishes, it will be destroyed by strong solvents, if they are spilled over the dried films.

Many new resins are becoming available to the paint industry and some have already found a place for themselves. One such resin is a copolymer of Styrene and poly-isobutyliene, a product of the extensive work on synthetic rubbers in the last decade. This is the Goodyear "Pliolite" which is also an outstanding material for use on concrete and cement-asbestos board. This resin has the ability to be dissolved in solvents containing as much as 50 percent of aliphatic hydrocarbons. The materials that can be used to plasticize this resin are limited by the lack of compatability, but they are sufficient in number to enable the paint chemist to make floor finishes for concrete floors that will withstand thousands of hours in alkali, and be able to resist more than 1500 strokes of a brush with tri-sodium phosphate solutions without failure or loss of gloss. This resin will offer to breweries, bakeries, laundries and other places where constant cleaning is required, films which can resist the alkali detergents and hot water used in scrubbing down these installations. These films made from Pliolite are mildew and chemical resistant and in general have the high resistance needed for decoration and protection in plants requiring constant washing for sanitary purposes.

The lack of solvent resistance in Pliolite coatings requires the education of the ultimate user in order that

all washing be done with detergents, not with solvents. This resin fills a much needed place in the field of surface coatings, and it will only be a matter of time before paint technicians find a means of improving the solvent resistance of these films, removing the principal handicap to more widespread use of this exceptional material.

We have mentioned only a few of the hundreds of resins available to the paint industry. These were selected because they are outstanding in a certain field—corrosion resistance—outside of the scope of normal atmospheric corrosion, and where unusual conditions exist.

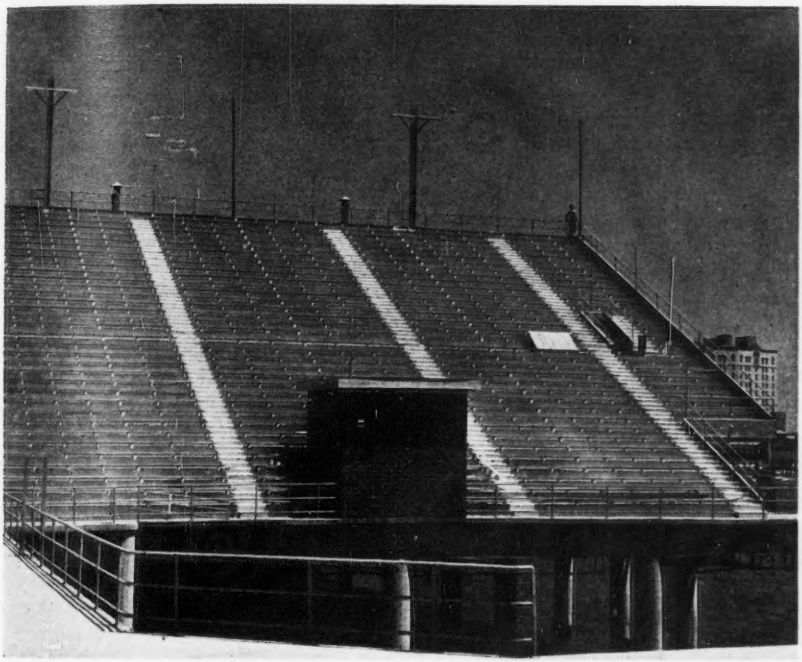
The paint industry maintains through its laboratories a constant search for new materials to improve the surface coatings it offers to its customers. Some of the new materials, to mention a few, are the silicones, whose high heat resistance promises to solve many problems.[5]

Another interesting material is Nylon[6] of which the paint industry has only limited experience and is now endeavoring to explore for new uses. Work to date indicates good alkali resistance for use in lining tanks containing caustics. What other uses will be found only time will tell.

Pigments

No discussion of corrosion resistant finishes would be complete without some reference to the very important part played by the pigments in the film. Pigments can be used for color, for decorative purposes, for protection or for combinations of all three of these functions. Some pigments are useful only for decoration and normal atmospheric corrosion resistance; others are limited for use only in top coats and some lend themselves more to primers and undercoats than to any other purpose.

The number of pigments now in use as primer or undercoat pigments has increased rapidly in the last twenty years. For many years red lead (Pb_3O_4) was the only type of metallic salt pigment used in primers on metallic surfaces where an inhibiting value was attributed to the pigment. Of course, the iron oxides and/or hydroxides have been used for many years and continue to be a large factor in the field of pigments for primers. The iron pigments were, and are, considered one of the outstanding pigments for use in primers. Experience based on several years' exposure tests indicates that, unless fortified with an inhibiting type of pigment (one preferably water soluble to some extent, such as the zinc yellow pigments [$K_2O.4ZnO.4CrO.3H_2O$] an alkaline salt of zinc, capable of supplying chromate ions), then the properties of the iron pigments are limited solely to color and the ability to resist changes due to normal atmospheric exposure. Iron pigments when used with zinc oxide and/or zinc chromate show increased corrosion properties over the same primers without zinc pigments. As little as 5 percent zinc oxide makes a remarkable difference in resistance to weathering as indicated by exposures of six months in Florida on steel panels. When 7 percent of the iron pigment is replaced with zinc yellow then the primer really displays outstanding performance when compared to both



A strenuous test for surface coatings is this steel stadium at the end of the Galveston, Texas, Pleasure Pier on the Gulf of Mexico. Located 1000 feet from shore, it is continually subjected to the effects of salt water spray, wind and hot Gulf coast sun. The stadium was painted with two coats of red lead primer and one of aluminum.

the iron pigment alone or the iron pigment plus 5 percent of zinc oxide in the same primer vehicle.

Among the prominent primer pigments now available in the paint industry is the zinc yellow which performed so excellently in the last war on aircraft, ships and other places where a truly inhibiting type primer was required. Much lighter than red lead, it lends itself to use on both ferrous and non-ferrous metals. Its ability to prevent corrosion, coupled with its relatively light weight, were prime factors in its excellent performance on aircraft skin sheets during the last war. As previously indicated, its hiding can be increased, and its good properties preserved by blending with other pigments. It is often used with lamp black to give it a green color when such is preferred to its natural bright clean yellow.

Not quite as popular as the zinc yellow are Strontium and Barium Yellows, where the metallic zinc is replaced with either of the other two metals. These are not as good under most conditions as zinc yellow, due mostly, it is believed, to the lower amount of available chromate ion

from these pigments. Where zinc yellow is used, it may be replaced with as much as 40 percent of mica or any other equal inert pigment with little loss of inhibiting properties. This has been proved by using blends of zinc yellow and mica (Figure 2), starting with a panel using 100 percent zinc yellow in the primer, and replacing the zinc yellow with mica in steps as follows: 75 percent zinc yellow—25 percent mica, 50 percent zinc yellow—50 percent mica, 25 percent zinc yellow—75 percent mica, and 100 percent mica. It is very evident from the results obtained after seven weeks in tide water in Florida on H_2So_4 pickled steel, H_3Po_4 pacified, that the 50-50 zinc yellow mica combination was on the very edge in protective qualities.

Panels containing zinc yellow were exposed in water containing varying quantities of Chloride (Cl) ion and sulfate (So_3) ion and combinations of the same. The results indicate that high concentrations of these ions promoted early blistering, while the chloride ion alone seemed to be even more active in blistering primer films than the sulfate ion.

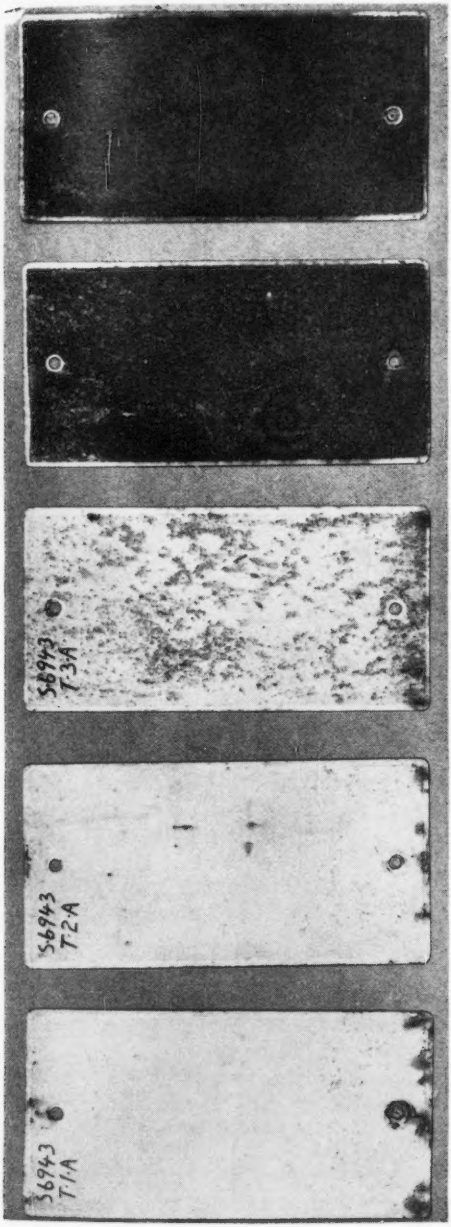
A relatively new primer pigment is the Basic Zinc Chromate ($4.5ZnO.CrO_3$), a non-water soluble pigment, used extensively in the "wash primers" spoken of in this paper under vinyl vehicles. This pigment when properly combined with the polyvinyl butyral film activated by an acid phase, proved to be an outstanding performer. Panels using red lead primer, wash primer, and a zinc yellow marine primer were exposed for seven weeks in tide water over clean steel, rusted steel and galvanized iron, and on each metal the wash primer was the best material, the zinc yellow next and the red lead poorest. As was indicated earlier in this paper, the red lead would have been better had the vehicle been improved over the linseed oil used by use of a phenolic base varnish.

Regardless of the vehicle used, or the pigment, it is evident that other factors play an important part in protecting metals from corrosive atmospheres. Some of these contributing factors are film thickness, preparation of the metal, method of application and time lapse after preparation before coating, and many others.

Experience has shown that adequately thick films are required in most cases for good protection. This differs in the case of wash primers, where a 0.3 mil film seems to yield best results, but in most primer applications, films up to 2 mils dry are indicated.

Metal surfaces should be clean, free of rust and ruptured scale or flaked and worn old paint films. Mechanical wire brushing is a fair practice, sandblasting is much better, and where indicated the use of shot blasting is excellent, but the metal should be clean and free of loose foreign matter and rust.

When cleaning as in sandblasting, it is essential that the cleaned surface be painted as quickly behind the sandblasting as possible. In no case should more than one hour be allowed to elapse, before the newly cleaned metal is coated in. Where new type, fast dry, wash primers are used the excess sand blown back over the primed area will rarely stick or imbed in the film because it dries so rapidly it does not allow sand



to stick in it. In most corrosive atmospheres the newly cleaned surface is left too long before recoating and minute spots of corrosion start on the bright surface. The primer film applied over such a surface will have lost some of its effective properties almost at once.

One of the best ways of treating metal for painting, on objects small enough, or in places where it is convenient, is to use a system of phosphate treating, forming a protective crystalline structure first, to which paint has excellent bond, and which will in itself aid in reducing underfilm corrosion.

The paint industry has continually strived through the laboratories of paint manufacturers and those of raw material suppliers to the industry to improve on the products it is manufacturing. The industry has a responsibility to fulfill to the users of paint and will continue to strive toward ever better products. Those responsible for the purchase and application of paint in the field of corrosion control should likewise expend every effort to see that these quality products, produced of years

Figure 2—Panels from left to right are coated with zinc yellow primer (U. S. Navy 52-P-18) showing effect of decreasing zinc yellow and increasing mica. They were exposed for seven weeks in Florida tide water, on steel, H_2SO_4 pickle, H_3PO_4 dip. Note loss of resistance and increase in rusting, (Panels-E. I. du Pont Co.)

of research and experimental investigation, are given every opportunity to fulfill their allotted task to the fullest measure by insuring proper preparation of the surface, application in strict accordance to the manufacturer's recommendations, and adequate drying time between coats that make up the system. Only in this way can the paint industry serve to its greatest efficiency, and the products of its laboratories, field tests, and production facilities be realized by the corrosion engineer.

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Present Day Aspects of Condensate Well Corrosion*

*By Harry E. Waldrip**

TO MANY, condensate well corrosion is an old, and to some extent, a sad story. To others it is a problem about which little is known.

Briefly, condensate well corrosion is the corrosive action on the producing equipment caused by the acid type waters produced by the high pressure type of gas condensate wells. These waters are acid because of the accompanying production of organic acids and/or carbon dioxide. Of course there are other contributing factors such as the rate of production, temperature of produced fluids and gas, ratio of condensate to water, composition of the produced condensate, composition of the produced water, condition and type of equipment, method of well completion and possibly others.

Characteristics That Help Classify Condensate Type Wells

Characteristics that help a petroleum engineer to differentiate between condensate wells and oil wells are:

1. Production obtained at high gas-oil ratios. The average gas-oil ratio values range from 66,000 to 7500 cubic feet of gas per barrel of liquid (15 to 130 barrels of liquid per million cubic feet of gas).

2. The produced liquid is normally water white, blue white or straw colored, although fringe oil production may result in a darker product.

3. Well depths range from 7000 feet down to the deepest producers.

4. High top hole pressures result from low or no fluid level in the hole.

Characteristics that help the corrosion engineer to recognize the condensate type well are:

1. The presence of organic acids (acetic-propionic types). The concentrations vary from 50 to 700 ppm as propionic acid.

2. The presence of acid well head waters. pH values at the well head range from 4.0 to 6.0.

3. The presence of appreciable carbon dioxide pressures. The range is from 0.20 to 4.50 mol percent or from 10 to 50 psi pressure in the well gas.

4. Relatively low salinity of produced water. The total solids usually range up to about 2000 ppm, although in some cases the salinities of bottom hole waters are approached.

5. Production of small amounts of water, i.e., from traces to 5-10 barrels daily.

6. The aqueous fluid usually con-

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tains up to 400 ppm iron as a result of subsurface corrosion. Extreme concentrations of 2000 ppm iron have been observed.

Using the above approximate criteria there are over 80 condensate fields in Texas, Louisiana, Arkansas and Mississippi. There are also about two condensate fields in each of the states of California, Colorado, Kansas and Oklahoma.

The corrosion of condensate wells differs from the ordinary oil well corrosion in that it is very rapid and if undetected in time may cause a wild well. Some newer deep oil wells in Louisiana and Mississippi produce carbon dioxide in the gas, organic acids in the water and suffer the same type of corrosion as do the condensate gas type wells. The work over jobs of condensate wells are much more costly than are oil well workovers. This figure usually ranges from $15,000 to $75,000 per well.

Methods of Detecting Condensate Well Corrosion

Fortunately there are methods of detecting the seriousness of the corrosion before it reaches the danger stage. These methods vary from those merely giving indications of the corrosion to those showing exact conditions. These methods are listed in order of their increasing accuracy: 1) Iron content of the produced water; 2) Well head coupon tests; 3) Otis Caliper survey instrument; 4) Visual inspection.

Determination of iron content of a produced water shows whether corrosion is occurring but does not show the type of corrosion (pit or general), or the exact rate. If the iron content falls in the range of 100-400 ppm the fluid is almost certainly corrosive. This method of determining corrosion has the advantage of being rapid, requiring no waiting period, although the services of a laboratory are necessary.

Well head coupons may be used to determine whether the well fluids are corrosive, but actual rates obtained are not applicable to the subsurface equipment. Well head coupon testing has been used extensively as a means of studying sets of metals in a search for corrosion resistant materials. The method is not recommended now as a means of determining exact well corrosion rates.

The Otis survey instrument has been an important development in furnishing information on the condition of the tubing below the surface of the ground. Prior to the development of this instrument there was no way, short of killing the well and pulling the tubing, to know whether the tubing was in good condition or seriously corroded. The Otis survey instrument is run into the well on a wire line under well pressure. After the instrument reaches the desired level, it is pulled upward recording the condition of the inner surface of the tubing on its upward travel.

Visual inspection is the best method for determining the actual condition of well equipment although the method is limited almost exclusively to inspecting Xmas trees and associated fittings. Prior to the time when subsurface surveys were available and particularly before corrosion resistant Xmas trees were on the market it was necessary to dis-

mantle Xmas trees at frequent intervals to determine their condition and replace necessary parts. Now that corrosion resistant master valves are available this is not necessary as there is less danger of a well getting away.

Costs of Condensate Well Corrosion

The costs incurred by corrosion of condensate wells are such as to warrant efforts to reduce them. Until recently while it was recognized from individual instances that these corrosion costs were high no data were available to show the average magnitude of the problem. Through the efforts of the NGAA Corrosion Research Project Committee some data have been obtained and it is possible to approximate the cost to several companies.

The average corrosion cost for five major oil companies was $3.80 per million cubic feet of gas produced. At a selling price of $50.00 per MM cu. ft. of gas, the corrosion costs based on gas alone, not including condensate production, is 7.6 percent of the gross revenue. For our own company the average cost of corrosion amounted to $5.90 per million cubic feet of gas. This is above the average of all five companies.

In order to show the extremes in corrosion costs, wells in different fields are taken as examples. One well that had to be worked over and tubing replaced after eight years of production cost $13,178 and produced 135,000 MM cu. ft. of gas at a corrosion cost of nine cents per MM cu. ft. of gas. Another well in a different field had to be worked over and the tubing replaced after 3½ years of very low production. This work cost $75,214 after only 178 MM cu. ft. of gas production had been produced over the 3½ year period. This corrosion cost amounted to $422.50 per MM cu. ft. of gas produced. Another well in the same field over the same period of time had a corrosion cost of $32.36 per MM cu. ft. of gas produced. Here the production amounted to 1931 MM cu. ft. of gas and workover and tube replacements cost $62,428. These latter two wells account for our $5.90 per MM cu. ft. of gas corrosion rate as compared with the five companies average of $3.80. This does not mean or show that a well is more corrosive at limited production; in fact the opposite is true. The tubing in both wells lasted approximately the same length of time. It simply shows that there was enough production in both wells to keep the tubing wet with the produced acid waters. If these wells had been operated at 5-10 MM cu. ft. per day it is doubtful if the tubing would have lasted a year. The examples are shown to demonstrate the extremes in corrosion costs in condensate wells. From a minimum of nine cents per MM cu. ft. of gas to a maximum of $422.50 per MM cu. ft. of gas.

Attacking the Corrosion Problem

While condensate well corrosion was unique to the oil and gas people when it was first discussed by Bacon and Brown,[1] before the NGAA in April of 1943, it is also unique in the manner in which the problem was attacked and at least some remedies developed. Industries in other fields could well follow the pattern followed by the various oil

and gas companies. Here was a problem concerning all producers and much too big a problem for each to solve alone. Through the cooperative efforts of the various companies in connection with the NGAA, our own NACE and between different individuals and companies great strides have been made.

Naturally one of the most logical solutions would be the use of noncorrosive low cost alloys. While the idea was sound and reasonable it was found that it was like running into a stone wall. Major tube mills were approached as to the possibilities of alloy tubing and its probable costs. Evidently the tube mills were not used to the type of cooperation so common among oil companies because our pleas were flatly ignored. This was not because their technical personnel did not appreciate our problem. They promised to do what they could. However no answer was forthcoming.

It was not until last fall that an alloy tube company presented actual field tests of 5 percent and 9 percent nickel steel tubing that had been in service for one year at Cotton Valley, Louisiana. These two alloys were displayed in sections together with the adjoining regular steel tubing. The comparison between the badly corroded common steel and the perfectly smooth nickel steel alloy tubing was amazing, and offers great promise. The tubing for the test was furnished by the Babcock and Wilcox Company. They stated that the 5 percent nickel alloy steel tubing could be obtained for 1.5 times the cost of N-80 tubing and the 9 percent nickel alloy steel tubing could be had at a figure of 3.86 times the cost of N-80 tubing. These increased costs over ordinary steel tubing would seem to be much greater than the added nickel justifies. The manufacturers should consider that there is a potential market of 2400 miles of this or some other suitable alloy tubing providing the price is right and just. This estimate is only for condensate type wells. As mentioned before, deeper oil wells in Louisiana and Mississippi exhibit corrosion of the same type as condensate wells and could well use a corrosion resistant type of tubing. An added feature offered by the 9 percent nickel alloy tubing is that it has a minimum yield of 90,000 psi.

By the time this report is made the results of the NACE test container in which 32 different alloys were tested by seven different companies will be known. V. V. Kendall prepared a paper which covers the results obtained in the testing of the 32 alloys. (This paper will be reproduced in CORROSION at a later date.)

Another method of combating the corrosion in condensate wells has been the treating of the produced water. This is divided into two general methods. One has been to inhibit the corrosion by the use of chromates. This was reported by W. D. Yale[2] of the Texas Company in the Erath field. Here the iron content of the water has been reduced from over 150 ppm to less than 5 ppm. Coupon tests show a reduction of from 88 to 96 percent. This method has been tried in other fields but the most successful and extensive treatment has been in the Erath field.

The other successful method is to neutralize the organic acids by the use of alkaline materials. To date this method is only being used in

wells of the true condensate type or in waters of below 2000 ppm total solids. P. L. Manual[3] has reported that the Stanolind Company is successfully combating corrosion by the use of ammonia. R. C. Buchan[4] of the Humble Oil and Refining Company has reported that they are using soda ash very successfully at Katy field. He estimates that by the use of soda ash their corrosion costs in the Katy field will be reduced from $200,000 per year to $50,000 per year.

Our own company is obtaining very good corrosion protection by the use of sodium bicarbonate. We prefer this chemical because of its lower pH. Experiments show that it is much less likely to precipitate calcium carbonate and thus reduce or eliminate the possibility of plugging. In one field where continuous injection is used the iron has been reduced from 275 ppm to about 15 ppm. In another field where the tubing is set on a packer and the annular space is mud filled, the chemical solution is lubricated into the tubing while the well is shut in. In this field the wells are shut in daily because of gas demand, so this intermittent treatment offers no problem. Here the iron content has been reduced from 260 ppm to about 15 ppm.

Methods of treating the hydrocarbon phase with various organic materials so as to produce a protective hydrocarbon film has been proposed and several have been and are being used and tested. To date the results are varying, some good and some not so good. In general this is a more costly and sometimes uneconomically feasible method of combating corrosion.

The success of the various types of treatment follow:

The total number of condensate wells reported from twenty-three companies in answer to a questionnaire sent them was 1334. This includes several dually completed and a few triple completed wells. Of this total, the number that are being or will be chemically treated by all methods is 232 or 17.5 percent.

The number of wells being successfully treated with neutralizers is 53.

The number of wells being successfully treated with chromates is 49.

The number of wells being successfully treated with organic type inhibitors is 28.

The benefits of the above treatments have been such that the treatments are going to be extended to additional wells in the near future and are listed as follows:

Number of wells to be treated with neutralizers 63.

Number of wells to be treated with chromates 8.

Number of wells to be treated with organic inhibitors 3.

In addition to the above treating and proposed treating there also are listed treatments that are going to be and are being tested experimentally. They are as follows:

Number of wells to be tested with silicates 12.

Number of wells to be tested with neutralizers 1.

Number of wells to be tested with alkali chromates 12.

Number of wells to be tested with chromates 2.

Number of wells to be tested with organic inhibitors 1.

A recapitulation of all the above successful treatments, proposed treatments and experimental treatments are as follows:

Neutralizers including silicate 129 wells.

Chromate 59 wells.

Combination alkali chromate 12 wells.

Organic inhibitors, polar compounds 32 wells.

It will be noted from the above that there are a great number of wells that are not being treated. There are several reasons for this. Some of the most important reasons follow:

1. Low rate of production, wells show no serious corrosion.

2. Wells appear to be of non-corrosive type.

3. Tubing set on packers, annulus mud filled making treating difficult or impossible.

4. Wells shut in because of lack of flow lines, lack of market for gas or other reasons.

If it were physically possible several wells would be treated that are now untreated.

The use of coated tubing has been used with some degree of success in some fields. One field reports 30 strings of plastic coated tubing. Several have been in operation two years without a breakdown. In four, failure occurred in 18 months and in three, failure occurred in six months. On the whole they report that it is economically feasible to use coated tubing. It must be realized that coated tubing is not a permanent installation. It is a temporary treatment that prolongs the time between workovers. While this is desirable and in the absence of anything better, it was worth considering. The cost is about the same as some alloy tubing.

While the final answer is not complete we are no longer staggering in the dark. The future picture appears to be as follows:

1. The use of alloy tubing of nickel steel or other suitable variety for all new tubing installations and all tubing replacements.

2. Treating present wells whose waters are of the low total solids variety with one of the tested alkali materials, soda ash, sodium bicarbonate or ammonia.

3. Treating present wells with chromates. Production should be watched closely to forestall possible chromate plugging.

4. If either of the above water treating systems are unsuited for a particular well, try treating the wells with one of the organic or polar compounds.

5. If well cannot be successfully treated to retard corrosion cross your fingers and wait until you can replace the tubing with a suitable alloy tubing.

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DISCUSSION

*By T. S. Zajac**

Mr. Waldrip's paper is a good summary of the progress being made on the condensate well corrosion problem and should serve as a helpful guide to those individuals who are starting to work on this problem. His data on types of chemical treatments being used and on types being considered for testing illustrate the diverse characteristics of the wells and the well fluids requiring treatment. Chemical treatments to date, for one reason or another, have found application in only a relatively small percentage of the total number of condensate wells requiring corrosion protection, and this strongly indicates the need for a protective measure of more universal application; e.g., corrosion resistant tubing. This, however, does not necessarily mean that corrosion resistant tubing will be the most economical solution in all cases even though it may appear to be the simplest and the least bothersome measure. An overall evaluation of the individual well's reserves, life, corrosive characteristics, and of the economics of the various corrosion prevention measures applicable might easily dictate the use of measures other than corrosion resistant tubing.

The author's discussion of Chemical treatment is quite comprehensive, however, no mention is made of treating those wells whose annuli are mudded off. For the sake of completeness and because this type of well completion still poses a problem to an appreciable number of operators, a brief mention of recent developments utilizing solid inhibitors follows. A number of tests using inhibitor sticks of controlled solubility, inorganic and organic, are currently in progress and results obtained to date appear quite promising for sucessfully extending the use of corrosion inhibitors to those wells which up until recently could not be treated with liquid inhibitors via the static casing-tubing annulus. The method of feeding chemical is relatively simple. The chemical is loaded into the lubricator above the master valve and opening the valve drops the chemical down the tubing. This operation is usually performed at very low flow rates or zero flow rates to allow the stick to go to bottom.

* Shell Oil Company, Inc., Houston, Texas.

AUTHOR'S REPLY

The reason the stick type of treatment wasn't mentioned in my article was that at the time my article was written only a small amount of experimental work had been done on this method of treating. When I secured my information from the various companies on the types of treatment being used the use of sticks was not a factor.

Since that time more experimental work has been done on treating wells where the annulus is packed off. Both sticks and liquid treatments have been tested and will be extended to regular treatment of this type of well. At the time the original paper was written the treating of wells with the annulus mudded off was not a proven method and therefore no mention was made of it.

Topic of the Month

CORROSION OF COPPER IN HYDROCHLORIC ACID

*By Paul J. Gegner**

TURBINE GENERATOR windings are cooled in a closed air cooling system, employing water-cooled copper tubes. To maintain a high heat transfer efficiency the tubes are cleaned every few weeks to remove scale deposited from hard cooling water. A 16 to 20 percent solution of hydrochloric acid, inhibited with one percent of a commercial acid inhibitor, is flushed through the system until removal of scale is complete.

The tubes began to leak within a year after the removal of scale was begun with hydrochloric acid solution. Inspection indicated that the leakage was caused by excessive corrosion on the interior of the tubes, apparently from attack by the acid.

Although copper is not fully resistant to hydrochloric acid, the rate of attack ordinarily is not excessive at concentrations up to about 24 percent. (The exact rate varies appreciably with the degree of aeration.) Figure I shows that in 18 percent unaerated hydrochloric acid, even in the absence of an inhibitor, the corrosion rate is not too high for intermittent exposure, as in the case of periodic tube cleaning. The presence of an inhibitor reduces the corrosion rate markedly, as shown.

The tube sheet and header of the generator air coolers are made of steel, but galvanic action, which is appreciable in an iron-copper couple in acid solution, could not, of course, account for the accelerated attack. Copper is cathodic toward iron and the attack would be expected to be concentrated on the iron.

The rusted condition of the tube sheet and header finally led to the conclusion that the accelerated attack on the copper tubes was caused by the presence of ferric ions in the acid, resulting from the solution of rust scale from the tube sheet and header. Ferric ions in non-oxidizing acids such as hydrochloric acid are strongly corrosive toward copper.

To illustrate the increased rate of attack on copper in iron-contaminated hydrochloric acid, some laboratory tests were conducted. Strips of copper were immersed in unaerated 18 percent acid at 82° F. for periods of 1, 3, 16 and 24 hours.

Figure I shows the corrosion rates

* Pittsburgh Plate Glass Co., Columbia Chemical Division, Barberton, Ohio.

in uninhibited and in inhibited acid, in the absence of iron, and in the presence of one percent ferric chloride (0.34 percent Fe). The influence of the inhibitor in retarding the corrosion of copper in acid solution is plainly shown, as is the accelerating effect of iron in the acid.

With the degree of aeration to be expected in a tube cleaning operation, the rate of attack is undoubtedly much higher than indicated. To reduce the concentration of iron in the cleaning acid, the tube sheet and header were cleaned and painted. This apparently reduced the corrosion rate since there was no tube failure reported for well over a year. Unfortunately, before it could be conclusively established that the elimination of iron from the system prevented excessive corrosion of the tubes, the descaling problem was solved by treatment of the water with hexametaphosphate. The soft scale now formed in hot weather is removed merely by blowing air through the system.

Despite the lack of confirmation of the effect of iron in the acid on the corrosion of the copper tubes, it is believed the laboratory test results are of sufficient interest to warrant mention at this time.

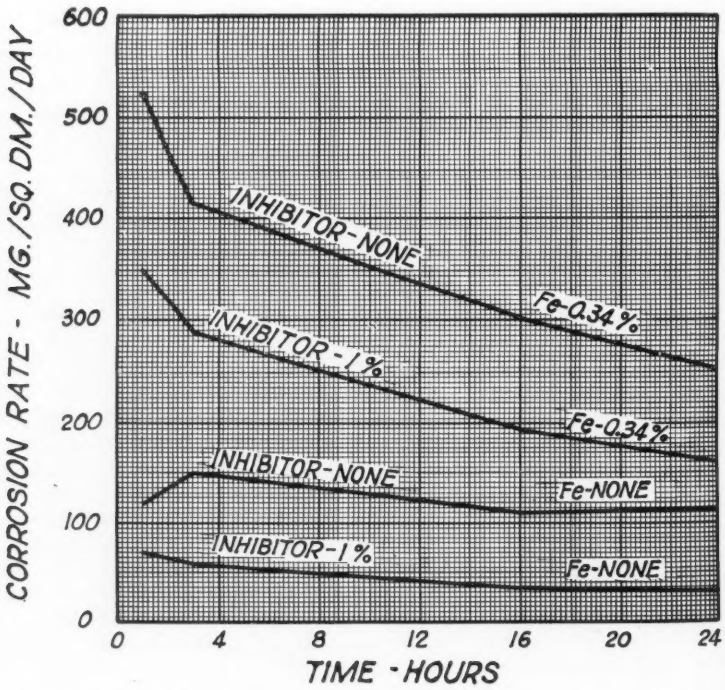

Figure 1— Corrosion of Copper in Hydrochloric Acid. Acid concentration 18 percent. Temperature 82° F. Aeration none.

Corrosion

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NACE News

"Marine Fouling," and its application to circulating sea water tunnels, heat exchanger equipment, condenser tubes, metal piling, ship bottoms and other structures was the scheduled topic of a talk and discussion for the December 1 meeting of the Western Region. Dr. Denis L. Fox, professor of Marine Biochemistry, University of California, La Jolla, Calif., was the programmed speaker. The discussion also is scheduled to include antifouling paints.

The Roger Young Auditorium, Los Angeles, Calif., is the announced place for the meeting and the dinner preceding it.

The program is one of a series arranged on the Pacific Coast.

A trip through the Springhill Paper Mill at Springhill, La., was the feature of the Shreveport Section meeting October 21. Mill personnel explained its operation.

Mill employees who are NACE members were hosts at a chicken dinner to the forty attending.

After dinner mill employees were introduced and a motion picture on steel making was shown.

"Historical Approach to Rocket Travel" was the topic of a talk scheduled for the November 15 meeting of the St. Louis Section, North Central Region. Ralph L. Maisak, a member of the American Rocket Society, scheduled to give the talk, also has had personal contact with early developers of rockets and their fuel, including Von Opel, Fritz Ober and Robert Goddard, planned a discussion of the problems of high temperature corrosion incidental to development of rockets. Mr. Maisak, who still is active in this field, illustrates his talk with slides giving details of the V-2 motor, and views of the earth taken from an altitude of 160 miles. He also gives demonstrations of rocket fuels.

Officers elected at the October 18 meeting were Otto Fenner, chairman; Clarence Mange, vice-chairman; E. Ghent Johannes, secretary-treasurer; William F. Gross, corresponding secretary. Problems of the manufacture of porcelain lined equipment was the topic of an illustrated talk by E. F. Meier, Monsanto Chemical Corp.

Tulsa Section, South Central Region, NACE, held its final 1948 meet-

ing November 5, at the Mayo Hotel, Tulsa, Okla.

"Field Tests of Sodium Chromates and Alkalis for Controlling Corrosion in Gas Condensate Wells," was the topic of a paper prepared for presentation by C. Kenneth Eilerts, principal physical chemist, Petroleum and Natural Gas Branch, Bureau of Mines, Bartlesville, Okla. This topic is considered of major interest to the oil and gas industry.

Problems of organizing regional divisions and local sections of NACE was the scheduled open forum topic for the joint meeting of the Metropolitan New York Section and the Northeast Regional Division December 7 at the Building Trades Employers Association, 2 Park Ave., New York, N. Y. George Diehlman of the National Lead Company was scheduled to talk on "Protecting Metals with Organic Paint Coatings" following the forum.

Officers elected by letter ballot for the Metropolitan Section were announced as follws by Frank LaQue: W. E. Shaw, National Lead Company, chairman; Dr. T. P. May, International Nickel Company, vice-chairman, and F. J. LeFebvre, of the Electro Rust-Proofing Corporation, secretary-treasurer. This section, with about 190 active NACE members, plans four meetings a year, each session to cover a different phase of the corrosion problem.

Meeting Time Changed—A joint meeting of the Philadelphia Section and the North East Region was held December 2, instead of November 17 as originally scheduled.

Chairmen of each section in the Northeast Region will appoint a section officer as interim trustee pending amendment of by-laws, the Board of Trustees, Northeast Region decided at a November 1 meeting in New York City. A. V. Smith has accepted chairmanship of the regional nominating committee on which A. S. Brooks and E. B. Mears will serve.

"Underground Corrosion," a talk by Dr. Irving A. Denison, and a discussion on "Electrolysis" led by Kirk L. Logan, both with the National Bureau of Standards, were scheduled features at the Southeast Region meeting in Atlanta, November 27. Dinner at 6 p.m. was a feature of the gathering at the Henry Grady Hotel.

Capt. H. A. Ingram, planning officer of the San Francisco Nevy Yard, a recognized authority on marine corrosion, addressed the San Francisco Bay Area Section of the NACE at P.G.E. Auditorium, Oakland, Calif., October 12. His topic was "Marine Corrosion."

DIRECTORY OF MEMBERSHIP

The Current Directory of Membership of the National Association of Corrosion Engineers will be published as a supplement to the January, 1949, issue. This is a departure from the custom in former years of incorporating the directory in the January issue. All who normally receive the January, 1949, issue also will receive the Current Directory supplement at no extra cost. This change has been made both to give subscribers a directory in a convenient form and to permit the use of every inch of space in the magazine for corrosion material.

GENERAL INTEREST

Southern Gas Association sponsored October 22 at the St. Charles Hotel, New Orleans, a Conference on Corrosion and Cathodic Protection.

Discussions during the day included the following subjects: Use of Galvanic Anodes for Cathodic Protection, Problems of Cathodic Protection, Problems of Corrosion in Distribution Systems and Instrumentation. The 37 present evidenced keen interest throughout from the opening at 9 a.m. to adjournment at 5:15 p.m., 45 minutes after the scheduled time.

Sidney E. Trouard, New Orleans Public Service, Inc., presided. Assisting Mr. Trouard in recording the discussions, and participating in them were C. L. Woody, Houston, and A. W. Peabody, Jackson, Miss., both of Ebasco Services, Inc.

An award of excellence was given for improvement in appearance in CORROSION magazine during the past year by the Southwestern Association of Industrial Editors to W. M. Wernett, who was managing editor during the award period. The SAIE gave Mr. Wernett a suitably inscribed certificate.

To house additional laboratories required for its ever-expanding research, Battelle Institute, Columbus, Ohio, will begin construction of a new half-million dollar laboratory building late this year. This structure is scheduled for completion in 1949.

Abstract Contributors—Added to Corrosion's list of abstract contributors are: Index to Current Technical Literature, Bell Telephone Laboratories, and the Technical Data Digest, Air Materiel Command—Technical Service Section.

New Feature to Be Introduced

With the introduction of the new size Corrosion magazine in January, a Questions and Answers Department will be incorporated under the title of "Corrosion Problems." The new feature will be edited by L. G. Vande Bogart of the Crane Co., Chicago, Illinois.

Questions will be given a serial number and may be reworded by the Editor. Questions should carry sufficient detail to completely describe condition and problem. Proprietary trade names may be used in presenting problem, but the editor reserves the right to reword both questions and answers before publication in order to delete such trade names. Selected questions will be printed, and readers are invited to send in answers. Where answers are incomplete or there is a disagreement, a committee will screen answers and decide on an answer or agree to print various viewpoints.

All questions will be the property of the Association. The questions which are not printed will be circulated to the above committee and answers sent to the correspondent privately.

Authors of questions will remain anonymous to readers while authors to answers may remain anonymous by request. In general, it will be better to have names of authors of answers. Authors of both questions and answers should give name and company affiliation and submit them to: L. G. Vande Bogart, 836 South Michigan Ave., Chicago, Illinois.

PERSONALS

S. T. Shultz, for 17½ years paint chemist with The Texas Company and recently corrosion engineer with Natasco, has contracted with the Arabian-American Oil Company, Saudi Arabia, to be its chief corrosion engineer for all operations in the Near East. Mr. Shultz departed for Dhahran, Saudi Arabia, November 15.

His work will cover the entire paint and protective coating problems and other control measures for refinery, marine equipment, pipe lines, homes and all other installations. Crudes from the Saudi-Arabia wells are sour and extremely corrosive, Mr. Shultz reported, with sulphur content in excess of that found in West Texas.

John C. Dean has been appointed head of the Industrial Chemicals Section, Development and Research Division, International Nickel Co., Inc. He has been associated with the section since 1942. A graduate of Brown University, he holds an M.S. degree from that institution where he specialized in metallo-organic chemistry. He also holds a Ph.D. degree from Columbia.

Effective October 25, **Norman E. Hamner,** most recently with the editorial department of The Houston Chronicle, became managing editor of CORROSION, succeeding W. M. Wernett, who has held the position during the past two years.

Mr. Hamner, prior to service with the infantry in the European Theater during World War II, has had 20 years of experience in the editorial, advertising and printing departments of daily and weekly newspapers in Louisiana and Texas. He has been a resident of Houston since his separation from the army two years ago.

George E. Purdy, formerly with General Chemical Company, has joined the staff of the Tretolite Company Research Laboratory at St. Louis, Missouri. Mr. Purdy will engage in investigation of corrosion problems, and in development and application of corrosion inhibitors. He is an engineering graduate of the University of Missouri, School of Mines and Metallurgy, and a member of Alpha Chi Sigma.

Hugh J. McDonald recently was appointed professor of physical chemistry and chairman of the department of chemistry, Loyola University School of Medicine, Chicago. He had been professor of chemistry and director of the Illinois Institute of Technology Corrosion Research Laboratory, Chicago. He is a member of the NACE board of directors, representing the North Central Region and chairman of "Symposium on Corrosion Principles," for the 1949 Conference.

R. McFarland, technical director for Hills-McCanna Company, Chicago, Ill., has accepted appointment as CORROSION's correspondent for the Light Metals Section. His interest in non-metallic constructional materials and the special information available to him as a result of the nature of his company's work is expected to be of material assistance to those facing corrosion problems with these materials.

BOOK REVIEWS

An Introduction to Metallic Corrosion

By Ulick R. Evans; Longmans, Green & Co., Inc., 55 Fifth Ave., New York 3, N. Y. Price, FOB New York, $3.25.

Written primarily for use as a text in teaching corrosion principles and methods of prevention, the book explains the fundamentals underlying corrosion of metals and practices which may be used to overcome these destructive forces. Effects on corrosion of various environments, stress and strain and structure are described. It also outlines principles of inhibition using soluble compounds and presents in a direct and simplified manner readily understandable by both student and experienced scientist the theories of electrochemical corrosion of dissimilar metals with or without applied currents. Consideration also is given to the various mechanisms of corrosion prevention in present use with detailed tests for their efficacy. The book is of definite value to engineers and students needing a better understanding of the science of corrosion. —MAJ.

Electric Instruments, Construction and Operating Principles—A Manual

Available from Distribution Section, Adv. & Sales Promotion Div., General Electric Co., Schenectady 5, N. Y. Per copy, $1.00.

Purpose of this manual is to contribute to the more effective use of electric instruments by explaining their operating principles and illustrating the application of these principles in the instruments commonly used for electrical measurement. Structural features are described in details sufficient for understanding of function, although the manual is not intended to teach instrument design, nor is it intended to serve as a guide in application. All basic electric measuring instruments are treated and consideration is given to many special instruments evolved from the fundamental form. Instrument types considered: Permanent-magnet, moving coil, rectifier, thermocouple, moving iron—ammeters and voltmeters, synchroscopes, frequency meters, recording and specialized types.—MAJ.

NEW CORPORATE AND ASSOCIATE MEMBERS

Following is a list of new Corporate and Associate members who have joined NACE during the period from October 16 to November 16, 1948, bringing to 247 the number of these types of sustaining Association memberships:

Corn Products Refining Company (Chemical Division), Argo Illinois	**R. W. Flournoy**
Crane Company, Chicago, Illinois	**L. G. Vande Bogart**
Creole Petroleum Corp., Caracas, Venezuela, S. A., Jan. 1st	**F. J. Amador**
Laclede Gas Light Company, St. Louis, Mo.	**C. E. Schoene**
Myers, L. E., Company, Chicago, Ill.	**Newton D. Rich**
National Aluminate Corp., Chicago, Ill.	**J. W. Ryznar**
Plastic Lining Corp., Chicago, Ill.	**C. A. Van Natta**

NEW PRODUCTS, MATERIALS AND SERVICES

Literature

SEAMLESS TUBES and pipes in sizes more than double those available before the war are being made by International Nickel Co. at its Huntington Works with a 4000-ton extrusion press. Materials include nickel, Monel and other high nickel alloys in diameters up to 9¼ inches and lengths to 12 feet.

"HIGH-TEMPERATURE Ceramic Coatings for Molybdenums," Technical Report 1296, National Bureau of Standards, U. S. Department of Commerce, Washington 25, D. C., details results of tests seeking to find a coating useful at temperatures in excess of 1800° F.

THICKNESS DETECTOR improved to include such features as adjustable frequency modulation to facilitate measurement from one side of seriously corroded equipment is announced by Branson Instruments, Inc., Danbury, Conn. The original, "Audigage" instrument was introduced two years ago.

DATA SHEETS showing fatty acid components of the most commonly used fats and oils, a color standards comparator and temperature conversion tables are offered by the W. C. Hardesty Co., Inc., Los Angeles 22, Calif.

LOW-TEMPERATURE Properties of 18:8 Chromium-Nickel Steel, Technical Report 1285, National Bureau of Standards, U. S. Department of Commerce, Washington 25, D. C., covers tests of the mechanical properties of austenitic 18:8 chromium-nickel steels at temperatures down to —188° C.

INCREASED LABORATORY, operating and warehouse space will be provided at a new San Antonio, Texas, unit of the D. W. Haering & Co., Inc.

RED LEAD Primers for Atmospheric Exposure, Technical Letter No. 3 of the Lead Industries Association, 420 Lexington Ave., New York 17, N. Y., gives eleven formulas.

SIX-TON CLAMPS of chromium-nickel stainless steel have been used to hold, lower and lift stainless steel plates ½ inch to 2 inches thick during the pickling process at the Carnegie-Illinois Steel Corporation's Homestead Works. In use thirteen months, the clamps show no serious deterioration although they are lowered into the acid and remain immersed from 40 to 60 minutes for each plate.

MINIATURE BALL bearings is the subject of a catalog by the Miniature Precision Bearings, Inc., Keene, N. H. More than 40 types of standard miniature ball bearings are listed.

AN ADDITION to the B. F. Goodrich Tuscaloosa, Ala., plant now under construction is designed for lining with rubber tank cars and other containers used in the transportation of chemicals.

SINCLAIR REFINING Company's ultra-modern research and development laboratories at Harvey, Ill., were opened October 22. Included are nine buildings providing 215,000 square feet of floor space, covering 20 acres of a 38-acre site.

"PREVENTING CORROSION in Export Packaging" is a new, illustrated, "how to do it" guide to good export packaging by Dearborn Chemical Company, 310 S. Michigan Ave., Chicago 4, Ill. Copies are available through the Chicago office.

ATLAS ENGINEERING Works, Houston, will be exclusive worldwide sales agency for the "Dreadnaught" line of oil well exploratory, producing and drilling equipment. The equipment is made in Beaumont, Texas, by the Beaumont Iron Works Co., a subsidiary of the American Locomotive Co.

CHEMICAL ANALYSIS of Metals document entitled "Recommended Practices for Apparatus and Reagents for Chemical Analysis of Metals" (E-50) has been developed by ASTM Committee E-3. Detailed descriptions of recommended equipment and for preparing standard solutions are included and the data are considered very helpful by chemists and analysts using ASTM methods. Copies can be obtained from ASTM Headquarters, 1916 Race St., Philadelphia 3, Penna.

STANDARD PRODUCTS for corrosive and high temperature service comprising about 200 items are included in an International Nickel Co., Inc., catalog "Standard Specialties" available from the company's 67 Wall Street, New York, offices.

STAINLESS STEEL valves, accessories and fittings are catalogued in a new Cooper Alloy Foundry Co. publication. Copies may be obtained from the company's Hillside 5, N. J., offices.

SILICON-BRONZE 609 self-tapping corrosion resistant screws have been developed by the Bridgeport Brass Co., Bridgeport 2, Conn., for outdoor construction. They are being offered with tensile strengths from 80,000 to 100,000 psi.

LIST OF periodicals, guides and other publications on nickel alloys, stainless steels and nickel cast irons is offered by International Nickel Co., 607 Wall Street, New York.

• ***Reprints of the article Management Information on Cathodic Protection of Buried Metallic Structures Against Corrosion by the Correlating Committee on Cathodic Protection are now available in small quantities. This reprint which was originally published in the September, 1948, issue of CORROSION may be purchased from the Association in lots of ten or more at a cost of ten cents each. Orders should be addressed to: National Association of Corrosion Engineers, 905 Southern Standard Building, Houston 2, Texas.***

Corrosion Abstracts

ATMOSPHERIC CORROSION

Effect of Weathering on Various Rotproofing Treatments Applied to Cotton Tentage Duck. Rot-proofing Efficacy of Mixtures of Metallic Naphthenates. C. H. Bayley & M. W. Weatherburn, *Can. J. Res.*, F, **25**, No. 1, 92-109; No. 3, 209-220 (1947).

Loss in breaking strength on weathering of cotton duck treated with numerous rotproofing agents including copper, mercury and zinc naphthenates, cuprammonium and mineral khaki was in no case that of the untreated fabric. Petroleum base waxes added to the rotproofing treatments usually increased the breaking strength loss but reduced the loss of rotproofer by leaching. The weathering characteristics of cotton duck treated with copper or zinc naphthenate containing mercury naphthenate or phenylmercury naphthenate, and the effect of weathering on the rotproofing efficacy of these treatments, as judged by the soil burial method, have been investigated. The presence of the mercury compounds reduced the loss of copper during burial and did not affect the weathering properties of the treated fabrics. Binary and, to an even greater extent, ternary mixtures of different naphthenates showed in general

Abbreviations at the end of abstracts indicate source of abstract and contributor; and are as follows:

AER	*Aeronautical Review*, Institute of Aeronautical Sciences, Inc.
ALL	*The Abstract Bulletin*, Aluminum Laboratories, Ltd.
AWWA	*Journal*, American Water Works Association
BLR	*Battelle Library Review*, Battelle Memorial Institute Library
BNF	*Bulletin;* British Non-Ferrous Research Association
CALCO	Calco Chemical Division, American Cyanamid Corp.
CE	*Chemical Engineering*, McGraw Hill Publishing Co.
CEC	Consolidated Edison Co. of New York, Inc.
EW	*Electrical World*, McGraw Hill Publishing Co.
GPC	General Petroleum Corp. of California
INCO	The International Nickel Co., Inc.
IP	Institute of Petroleum
MA	*Metallurgical Abstracts*, Institute of Metals, London, Eng.
MR	*Metals Review*, American Society of Metals
NBS	National Bureau of Standards
RA	*Refrigeration Abstracts*, American Society of Refrigeration Engineers
RM	*Revue de Matallurgie*, Paris, France
RPI	*Review of Current Literature Relating to the Paint, Colour, Varnish & Allied Industries*, Research Association of British Paint, Colour & Varnish Manufacturers, London.
TDD	*Technical Data Digest*, Air Materiel Command—Technical Service Section
UOP	Universal Oil Products
No Code	*Current Technical Literature*, Bell Telephone Laboratories

greater resistance to attack than did samples containing the same percent of metal in the form of a single naphthenate.—RPI.

How Much Zinc Does Pole-Line Hardware Carry? B. J. Barmack, *Elec. Light & Power*, **26**, 68-73 (1948) Feb.

Discusses specifications for zinc-coating of the above and gives data on the effects of different methods of preliminary surface treatment and application on coating thickness and weight/sq. ft. Extensive charts give results of stripping tests. Suggestions are offered toward the solution of the problem of longer-life hardware.—BLR.

BEARING CORROSION

A Study of the Kinetics of Bearing Corrosion and Oil Oxidation: Correlation of Various Test Methods. Hugh R. Lehman & L. Kermit Herndon, *Eng. Exp. Sta. N., Ohio State Univ.*, **20**, 45-52 (1948) Feb.

Outlines a method of graphical analysis for the corrosion curves exhibited by the MacCoull Bearing Corrosion Tester. Application to such widely differing test methods as the Indiana Stirring Oxidation Test and the oxygen-absorption method of Dornte is demonstrated. This indicates existence of a method of correlating the extensive bearing-corrosion and oil-oxidation data in the literature. 12 ref.—BLR.

CHEMICAL CORROSION

Corrosion Phenomena in Steel Gas Cylinders. A. Steyaert, *Natuurwetensch. Tijds.*, **24**, 233-240 (1942); **Brit. Absts., BI,** 11 (1947) Jan.

Corroded steel gas cylinders contain ferric sulfocyanide, iron sulfide, carbon, sulfur, ferrous sulfate, ferric sulfates, iron oxides and carbonates, and also ferrous cyanide and/or ferric cyanide, but no Prussian-blue corrosion is caused by HCN, H_2S, CO_2, and H_2O. HCN removes the protective film on the steel and so facilitates corrosion. Corrosion can be reduced by total elimination of HCN and H_2O, and complete desulfurization is desirable. Corrosion by CO_2 and O_2 is reduced by these precautions and can be further reduced by coating surface with zinc or aluminum.—INCO.

Phenol as an Accelerator of Corrosion of Lead. F. Sandmeier, Translated extract from *Technische Mitteilungen der schweizerischen, Telegraphen-und Telephonverwaltung*, 1944-1945; original article is entitled Recognition of the Nature and Cause of Damage to Lead Cable Sheathing (in French and in German).

Reviewing available evidence in some detail, the author concludes that in the corrosion of lead the action of phenol is catalytic.—BNF.

Industrial Handling of Fluorine. Ralph Landau & R. Rosen, *Ind. & Eng. Chem.*, **39**, No. 3, 281-288 (1947).

The unusual physical, chemical, corrosive and physiological properties of fluorine are summarized, and its comparative heats of reaction and its effect on various metals and non-metallic substances tabulated. A schematic flow diagram used to study the latter at various pressures is shown. Dilute and pure fluorine have substantially different properties, while nickel, Monel metal, aluminium, magnesium, and metal fluorides in their highest valence states have excellent corrosion properties. Unexplained inhibited reactions sometimes occur. Standard or extra-strong iron pipes for atmospheric, and nickel and Monel-metal pipes for greater pressures are recommended for conveying, using welded joints. Flange joints, with soft copper, aluminium, or Teflon (tetrafluoroethylene) gaskets may be used for low pressures, while valves with Teflon as seating element and Monel metal or nickel as mating element are recommended, welded or silver (not soft) soldered into the line. Instruments, compressors, etc., must be selected with great care. Storage is hazardous, requires thick Monel-metal or nickel containers. Safety precautions, an efficient treatment for burns and successful disposal methods are described. Fireproof neoprene is a successful protective fabric.—MA.

Screening Device For Slurries of Organic Chemicals. J. G. Kern & Others, *Field Info. Agency, Tech., Final Report* No. 1012, 4 pp. (1947).

A high capacity screening device for slurries of organic chemicals has been developed for removing grit and coarse particles from slurries. Where applicable it has distinct advantages over vibrating screens, jet screens, fine grinding mills, etc.—MA.

Surface Effects During the Annealing of 70-30 Brass. I. Jenkins, *J. Inst. Metals*, **73**, No. 11, 641-665 (1947) July.

After reviewing the underlying difficulties in bright annealing brass, author

A GREAT *NEW* DOW DEVELOPMENT

Here's important corrosion protection news for you. It's GALVO-LINE, a revolutionary new type of magnesium anode developed by Dow.

GALVO-LINE is a flexible, continuous, magnesium ribbon anode, cored over its entire length to prevent segregation and provide lasting electrical contact. It's the most powerful of the magnesium galvanic anodes—develops three to seven times more current flow per pound of anode metal installed. With GALVO-LINE, current requirements are at a minimum because the current source is a *line* rather than a point—current is distributed more uniformly and utilized more efficiently at the protected structure.

But that's not all. Look at the picture above and you'll see how GALVO-LINE is installed simply, quickly, and at considerably less cost than conventional anodes. For pipe lines for example, it can be installed mechanically by means of a truck or tractor-driven wire-laying plow fed from a reel of GALVO-LINE mounted on the plow or truck.

GALVO-LINE is versatile, too! It makes the magnesium anode practical for use in relatively high resistance soils. In low resistance environments it exerts a powerful polarizing action which tames corrosion quickly . . . paves the way for a smaller, cheaper, long-term installation. And it's flexible . . . GALVO-LINE can be bent and formed to conform to the geometrical requirements of a variety of different applications.

Get the facts . . . write to Dow.

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CHEMICALS INDISPENSABLE TO INDUSTRY AND AGRICULTURE

describes experimental work to assess importance of the various factors. Annealing under a pressure of cracked ammonia restricted loss of zinc from the surface, but did not prevent staining, owing, it was found, to the evolution of gases largely originating from lubrication residues not removed during degreasing. *In vacuo* this did not occur but appearance was modified by loss of zinc. Author advocates process which has given satisfactory results on a semi-production scale with brass in coils. Discussion in *Metallurgia*, **36**, No. 216, 318-320 (1947) Oct.—BNF.

Metallic Contamination of Foods. J. T. Janson & C. E. Allen, *Canad. Chem.*, **24**, No. 8, 389-391, 394 (1940).

Metallic contamination of foods may result in discoloration (e.g., iron in tinned beet), impaired flavor (copper or iron in milk products), or toxicity. A tabulated summary shows observed variations in the natural copper, zinc, and arsenic content of 10 food products. Considerable amounts of tin, aluminum, and zinc may be derived from food containers and trays made from tinplate, aluminum, or galvanized iron.—MA.

Materials of Construction for Chemical Equipment. *Brochure Published by McGraw-Hill Publishing Co.*, New York 72 pp. (1947).

A good deal of the material in this publication has already appeared in *Chemical Engineering*, Nov., 1946. It includes an article on gasket materials; a list of metals and alloys, plastics, ceramics and other materials available to the chemical industry with American manufacturers; and a long table showing the behavior of metals, etc., towards a large variety of chemical compounds (this part is considerably extended as compared with the original). Very wisely, the compilers point out that "corrosion involves many more variables than this or any table can possibly recognize" and add that the data given should be used only as a guide.

New Developments in the Sulfite (Wood Pulp) Industry, *Pulp & Paper Mag.* (Canada) **48,** No. 1, 79-84 (1947). *Brit. Abst.*, **BII**, 139 (1947) May.

A review covering hydraulic barkers, pulping and pulp washing practice, screen room developments, blow heat recovery, drying by pressure rolls and by the Flakt process, multi-stage bleaching process and pH control of this operation, and the use of rubber and of nickel-chromium alloys containing molybdenum, tungsten and iron for contact with chlorine in bleaching plants.—INCO.

"Impossible" Glass. *Sci. Illustrated*, 3, No. 1, 30-33+ (1948) Jan.; *Sci. American*, **178**, No. 2, 81 (1948) Feb.

A new glass, the first ever known to resist hydrofluoric acid is announced by the American Optical Co., as a result of research carried on for the atom bomb project. One application may be substitution for platium and gold retort in laboratory work handling hydrofluoric acid. Results of immersion tests of the new phosphate glass, which contains no sand, are popularly presented. No damage was shown after 5000 hrs. immersion, whereas ordinary glass turned to a chalky mass within a few hours.—INCO.

COATINGS

Determination of the Thickness of Anodised Layers on Aluminum and Aluminum Alloys. W. Wiederholt, V. Duffek & A. Vollmer, *Korros u. Metallschutz*, **18**, 37-41 (1942); *Paint Tech.*, **12**, No. 142, 406 (1947).

The procedure of dissolving the coating in a mixture of aq. phosphoric acid and CrO_3 (found in preliminary experiments not to attack the metal appreciably) at 80° C. and determining the loss in weight or change in dimensions gave results agreeing to within 2-4% with metallographic measurements. This acid mixture is recommended for large-scale removal of such anodised layers, and for the removal of layers produced by chemical means.—RPI.

Drawing of Wire and Bar Stock Made Easier by Phosphate Coating. E. Schmid, *Stahl u. Eisen*, **62**, 968-972 (1942).

Nature of beneficial effect of phosphate coating on forming operations on the basis of precision-drawn tubes, oil absorptive capacity of phosphate coatings related to their thickness, and permanent deformation of phosphate coatings are studied. There is a general discussion of replica technique for microscopic study and plasticity of phosphate coatings, phenomena of adsorption, experimental data on the drawing of phosphate coated steel wire with oil emulsions and soap powder, and data on usefulness of this coating in the cold drawing of special-section steel bars. Photomicrographs shown.—INCO.

Coatings of Hardened Synthetic Resins as Anti-corrosive Materials. G. S. Petrov & A. V. Vassilieva, *Prom. Org. Khim*, 7,

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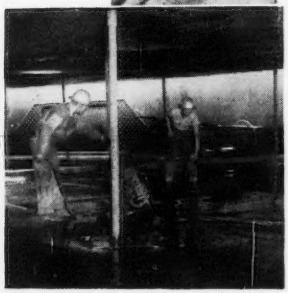

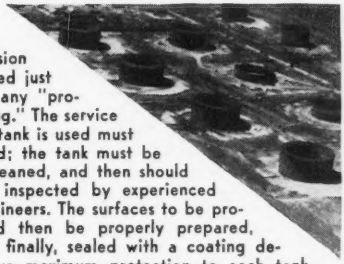

Adequate protection against corrosion is not obtained just by applying any "protective coating." The service in which the tank is used must be considered; the tank must be thoroughly cleaned, and then should be carefully inspected by experienced corrosion engineers. The surfaces to be protected should then be properly prepared, primed, and, finally, sealed with a coating designed to give maximum protection to each tank section from the particular type of corrosion encountered therein.

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No. 1, 48-9 (1940); *Peint. Pig. Vernis,* **17,** No. 3, 208 (1941).

Resols are the best materials for the production of coatings resistant to aqueous acids. They must be stoved at 16° C. The addition of plasticisers lowers their chemcal resistance.—RPI.

Rust-Preventive Coatings for Steel, and Miscellaneous Paints and Varnishes. U. S. Naval Tech. Mission in Europe, *Off. Tech. Serv. Report PB.* 3583 (1945); *Board of Trade, German Division,* F. D. 4525/47.

A report dealing with the manufacture in Germany of rust-preventive coatings.—RPI.

Moisture-Proofing and Fungi-Proofing (Tropicalizing) Medical Department Equipment. *Off. Tech. Serv. Report PB.* L 62801 (1945), 8 pp.; *NPVL Absts.,* No. 128, 310 (1947).

This bulletin deals with the failure of medical department equipment in tropical zones, the causes of these failures, and the means whereby the failures may be averted or overcome. The means discussed are primarily expedients. A description of moisture, fungi, salt, air, insects, and their part in equipment breakdown is presented. Prime consideration is given to the treatment of electrical equipment and the treatment of other materials is considered briefly. The technique of application of fungicidal lacquer is presented in detail.—RPI.

Exposure Tests on Coated Steel Panels. E. E. Jukkola, *Off. Tech. Serv. Report PB.* A 30523, 18 pp. (1943); *NPVL Absts.,* No. 127, 284 (1947).

Results of exposure tests on steel panels surface-pretreated with (a) a non-rusting zinc phosphate coating, flash-electroplated with zinc, and (b) a non-rusting iron phosphate coating, are reported.—RPI.

Relation Between Base Metal and Film as a Basis for the Corrosion-Preventive Action of Protective Coatings. O. Jordan, *Reichsamt Wirtschaftsausbau, Chem. Ber., Pruf-Nr.,* **15,** 125-53 (1942); *PB.* 52011; *Chem. Absts.,* **41,** No. 19, 6417 (1947).

Porosity, permeability to water and steam, condition of the metal surface, passivation with phosphoric acid, the reactions at the surface, protective film junction, the influence of the binder, the substitution of synthetic binders, and protection in sea water and of milk cans are considered.—RPI.

Transparent Oxide Coatings Protects Aluminum Surfaces. *Am. Machinist,* **92,** No. 4, 167 (1948) Feb. 12.

Announcement of the Anonizing process, an immersion method of protecting aluminum surface and maintaining its natural color. The transparent oxide coating resembles a clear glaze, though not brittle. On some alloys, as those containing substantial amounts of silicon, the surface of the metal darkens slightly. Coatings have good abrasion resistance, are resistant to smudging, oxidizing, finger marks, ordinary handling and high temperatures. Process consists of immersing cleaned aluminum into hot solution, then rinsing. Coating can be used as paint base. Announced by Technical Processes Div., Colonial Alloys Co., Phila.—INCO.

Primers for Ferrous Metals in an Atmospheric Exposure. New England Paint & Varnish Production Club, *Am. Paint J. Conv. Daily,* **30,** No. 6A, 5-7 (1945); *Ibid,* **31,** No. 6B, 34-36 (1946); *Brit. Absts.,* **BII,** 170 (1947) June.

A program has been drawn up for studying the protection of ferrous metal surfaces covering a period of 5 years. Exposure station is in a semi-industrial atmosphere with specimens facing south at 45°. Flat mild-steel panels and angle iron 4 x 4 x ⅜-12 in. specimens will be used. Fifty-eight primers will be investigated. Detailed formulations are given. One top-coat will in the first instance be used over entire series, but on selected panels will be supplemented by other topcoats. Diagram of exposure racks and details of climatic conditions at site are given.—INCO.

Protective Metal Coating. *Auto. Eng.,* **37,** No. 484, 23 (1947).

A temporary protective coating has been described in report PB-22825 of the U. S. Naval Technical Mission to Europe. The coating consists of a mixture of wool fat, china-wood oil, natural resin, white spirits, and a soluble dye. It is effective against rust, corrosion, and salt water, it does not melt when exposed to the direct rays of the sun, and it can be removed by washing in petrol.—MA.

The Plating of Plastics. *Brit. Plastics,* **18,** 428-432 (1946).

Review of subject. After preliminary treatment of the plastic surface by roughening and the removal of all dirt and grease, the coating of the plastic

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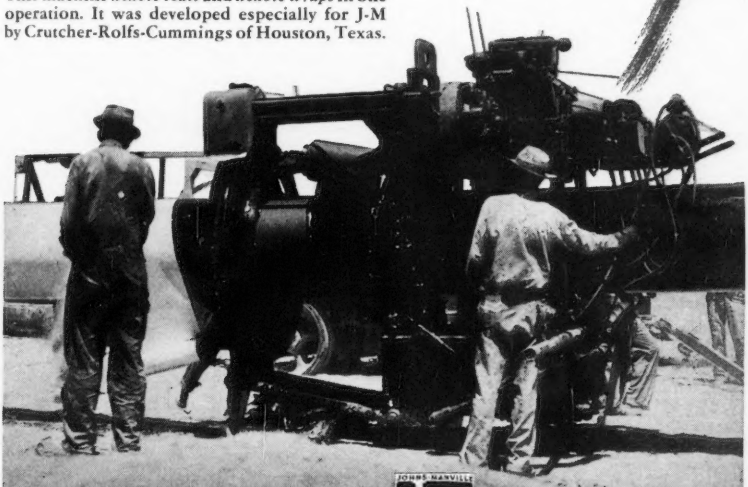

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with metal can be carried out by metal spraying, vacuum deposition, metal evaporation, cathode sputtering, brushing on, electrodeposition, or chemical reduction processes. Usually chemical reduction processes, in which gold, silver, copper, or lead compounds are reduced by formaldehyde, are used as a basis for further deposition. In most instances, the deposits render the plastic impervious to water, oil, and other solvents, they are corrosion-resistant as the inert base obviates electrolytic action, and they increase the heat-resistance. The deposits are usually thicker and the method is more expensive than plating on metal, but there are many applications in the production of intricate and difficult shapes, and of complicated conducting and nonconducting parts in aircraft work, in which the method is cheaper than electroplated metals.—MA.

A Study of the Dielectric Strength of Paint, Varnish and Lacquer Films. *Am. Paint J., Conv. Daily,* **32,** 8+ (1947) Nov. 8.

Describes apparatus and standard technique developed. Presents extensive test results for different organic films on steel, copper, tin, aluminum, nickel, Monel, and Inconel. The latter in the rolled and annealed state proved most suitable. Work is planned to determine whether the base-metal composition has any effect other than that due to its surface condition.—BLR.

New Wire Fabric Process Developed by Southwell. *Tool Engr.,* **19,** No. 6, 62 (1948) Jan.

News item mentions a new process for making an unwoven fabric of wire bonded with plastic which welds the joints and protects the wire against corrosion.—INCO.

The "Protecta-Tin" Treatment of Tinplate. *Tin,* 3-5 (1947) Dec.

Description of a method of producing a thin oxide film on tinplate to prevent the discoloration of cans by sulfur-containing foods, and of an improvement on this process which resulted in the tinplate being protected against rust also.—MA.

Action of Water. J. Van Loon, *Chim. Peint.,* **9,** No. 10-11, 308-310 (1946).

A general discussion of the sorption of water by paint films. The difficulties that arise in interpreting the quantitative results, when applied to so complex a material as an oil film, are explained as originating in the phenomena of oxidation and gelation which are continuous throughout the life of the film. The general conclusions that have been reached on rate and maximum amount of sorption and leaching are that these are dependent upon the thickness and age of the film, nature of drier, nature of medium and pigment. Fresh films sorb less water than aged films, and the sorption curve passes through a maximum.—RPI.

Test Methods for Evaluating Paint Fungicides. R. E. Vicklund & M. Manowitz, *Am. Paint J.,* **32,** 67-68 (1947) Dec. 1.

Several test methods for determining the mildew-resistance of paints were investigated and found to be unsatisfactory for laboratory evaluations of paint fungicides. A method is presented which was found to give reproducible test results in 7 to 10 days that correlated with results of exposures of painted wood panels in a tropical environment.—BLR.

Machining and Finishing Die-Castings. —Recommendations for Magnesium Alloys. *Mech. World,* **122,** No. 3168, 348-351 (1947).

Describes machining and surface-finishing techniques recommended for magnesium alloys by the Stewart Die-Casting Division, Stewart-Warner Corp. Finishing methods discussed include dichromate treatment, "manodyzing", and painting.—MA.

Corrosion Protection (of Aluminum Rivets). *Metal Ind.,* **70,** No. 16, 268 (1947).

Tests were carried out to find the best method of protecting milled aluminum alloy rivet heads against corrosion. Test specimens were two Alclad sheets, 3 x 6 x 0.125 in., riveted together with six or eight ¼-⅜ in. countersunk rivets. A number of protective treatments were applied to the rivet heads. Chromic acid was the best corrosive inhibitor of the acids; of the waxes, paraffin offered the best protection against salt spray.—MA.

Degreasing: Applications of a Synthetic Wetting Agent (Teepol X). *Metal Ind.,* **70,** No. 23, 425 (1947).

The improvements in aqueous degreasing effected by the use of Teepol X are described.—MA.

Painting Aluminum Alloys. *Metal Ind.,* **71,** No. 14, 287 (1947).

Description of the simple pre-treatments necessary to the metal surface before the application of paints to aluminum-base alloys.—MA.

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COATING	DESCRIPTION AND USES	CHARACTERISTICS OF EXPOSURES
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#23	A three component system recommended as an interior lining for steel and concrete storage tanks, tank cars, and process vessels. Prevents corrosion of the surface. Prevents iron or calcium contamination of the contained product. Resists abrasion, non-toxic to food products, easy to clean.	Various salts, dil… …rmaldehyde, alcohols, g… …ucts, beverages, and …
#44	A three component coating recommended for use in exceptionally severe conditions. Specially formulated to resist acids at higher temperatures and concentrations. Used for lining sodium hypochlorite tanks, hydrochloric acid tanks, sulfuric acid tanks, liquid fertilizer and distribution tanks.	Sodium hypo… …r crude, ammonium …
#31	A three component system recommended for constant immersion at temperatures up to 180° F. Excellent for dilute or concentrated solution. Used for lining stationary tanks, clarifiers and thickeners, ammonium nitrate and potassium chlorate storage tanks and equipment.	Caustic soda, calci… …oride, potash solutions, salt solutions, a… …rate, ammonium sulfate, potassium chlorate.
#55	A three component system recommended for constant immersion in concentrated salt or alkali solutions at temperatures up to 230° F. Particularly satisfactory for strong alkalies, such as 70% sodium hydroxide. No. 55 is not recommended for food products.	Hot caustic soda solutions, calcium and magnesium chloride, salt solutions, potassium chlorate.

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New Elastic Synthetic Builds up Extra-Thick Protective Coating. *Month. Rev.*, **34,** No. 11, 1298 (1947).

United Chromium, Inc. announces Unichrome Coating 218, which can be built up to extra-heavy thicknesses, and is primarily designed to insulate and protect electroplating racks. It contains 100% solids, with nothing to evaporate. It is a baking synthetic, applied by dipping or spraying, and upon curing at 350° F. becomes a sleek, elastic coating. On some racks thicknesses up to ¼ inch can be achieved within 2 hrs. on areas where such a degree of protection is desirable. It was found to withstand mechanical abuses without chipping, tearing, or lifting from equipment to which applied, and variety of strong chemicals in addition to hot cleaning solutions and all plating baths.—INCO.

Metal Spraying Processes. *Machinist,* (Eur. Ed.) **91,** No. 4 (1947).

The types of spraying guns used in the metal-spraying process, the use of spraying powders, and the liquid process as applied to tin, lead, cadmium, zinc, aluminum-silicon alloy, and pure aluminum, are described. The British argument that high quality is not possible with high-speed spraying is contrasted with the American argument that slow-speed spraying is uneconomical and results in a greater percentage of oxide in the coating.

Studies of Anti-Corrosive and Anti-Fouling Coating Systems for Ship Bottoms. *Bakelite Corp. OSRD Report* No. 6649. 306 pp. (1946) Jan.; *Prev. Deterioration Abst.*, **2,** No. 5, Lac 27 (1947).

Studies of anti-corrosive and anti-fouling coating systems carried on from Nov., 1940 to Aug., 1945 are reported. Sandblasting is the best cleaning method for ship bottoms. An effective wash primer, containing polyvinyl butyral resin, phosphoric acid, and a chromate pigment, was developed. The best anti-corrosive coatings contain vinyl resins and red lead or low-solubility chromate pigments. A new class of highly effective anti-fouling coatings was developed, containing a higher proportion of toxic ingredients and a matrix of high polymer synthetic resin, such as a vinyl resin.

Aluminum-Coated Steel May Offer Advantages for Many Products. *Prod. Fin.*, **11,** No. 5, 58+ (1947).

Aluminum coated steel is now being produced by a hot-dipping process by the American Rolling Mill Co. The finish is soft and satiny, but a brighter "extra smooth" grade is also available. The weight of coating is 0.50 oz./ft.^{2} on both sides, equivalent to a thickness of 0.001-in. per side. The material withstands up to 2000 hrs. in 20% salt spray at 95° F. (35° C.). It shows no discoloration below about 900° F. (480° C.), and no destructive scaling below about 1600° F. (871° C.) Tests have been carried out on car exhaust pipes, domestic-range oven liners, circulating boiler parts, etc.

Modern Trends in the Protective Coatings Industry. D. R. Wiggam,*Paint, Oil, & Chem. Rev.*, **110,** No. 17, 16+ (1947).

The production figures over a number of years of the various types of finishes are analyzed and the relative demands for oil and varnish paints, etc., are discussed. The trend towards the use of synthetic resin and polymer lacquers for industrial purposes is described. A short review of some of the newer synthetic coating materials (e.g., polyvinyl acetate, polyvinge-chloride, polystyrene, etc.) is appended.—RPI.

Protecting Mill Equipment with Hard Facing (Hastelloy CHF). G. E. Wilson, *Iron Steel Eng.*, **23,** No. 9, 63-66; discussion, 66-67 (1946).

Examples are given of the use of Hastelloy CHF for hard-facing steel-mill equipment. This is a nickel-base alloy, of Brinell hardness 210 (work-hardening to about 400), non-scaling and heat resisting, with low friction and high tensile strength and ductility; it may be welded electrically or with oxy-acetylene.—MA.

Laboratory Evaluation of Corrosion-Resistant Pigments and Vehicles. H. Zahn, Paper before Symp. on Corrosion Resistant Paints, Brooklyn Polytechnic Inst. May 4, 1946; *Paint, Oil & Chem Rev.* **108Z,** No. 16, 6-9 (1946); *Am. Paint J.*, **30,** No. 42, 68-69 (1946); *Corrosion,* **3,** No. 5, 233-240 (1947) May.

Negative potentials between a painted steel panel and tap water indicate that corrosion occurs. The effects of variables influencing this potential were investigated as well as the change in potential. Curves for typical porous and non-porous coatings were obtained. As the time of drying of porous coating before subjecting it to test was increased, the curve became similar to that of non-porous coating type. One vehicle decreased in its corrosion protection as it was pig-

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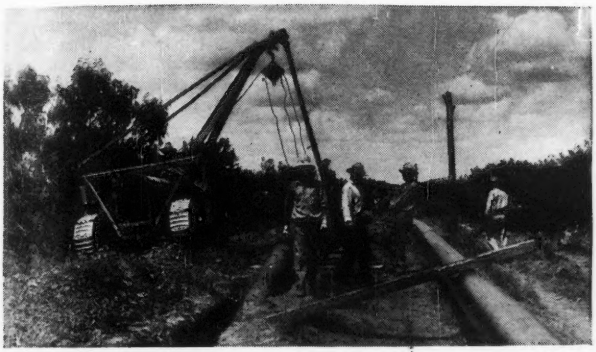

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mented, another was unchanged. The finish and pretreatment of the steel affected potentials greatly. Pickled and polished steel were about the same; rolled steel was superior and sand blasted panels were inferior in behavior. The order of protection conferred by surface oxide coatings was: 1) cold-rolled finish 1.07 mils, 2) a blue oxide surface 1.75 mils and 3) a straw-colored oxide surface 2.00 mils.—INCO.

Further Discussion of Paper (on) Chemical Corrosion-Resistance of Lead. Robert L. Ziegfeld, *Corrosion,* **3,** No. 7, 347-348 (1947) July.

Ziegfeld discounts Uhlig's warning as to the toxic effect of corrosion of lead piping.—MA.

Surface Activity of Lubricants. J. M. Wilson, Shell Oil Co., Paper before AISE Ann. Conv., Cleveland, Oct. 3, 1946; *Iron & Steel Eng.,* **24,** No. 8, 46-49; discussion 50-54 (1947) Aug.

Discussion of the nature of surface activity in lubricants as related to friction, wear, and protection against corrosion. 8 ref.—INCO.

Some Properties of Aluminum Flake Powders. Gunter W. Wendon, *Paint Mfr.,* **17,** 373-379 (1947) Nov.

Results of an investigation of the effects of shape and dimensions of the powders on their behavior in aluminum paint. Effect of method of manufacture on shape and sedimentation characteristics was determined. 10 ref.—BLR.

Slaughter House "Tough Jobs." R. Walter, *Food Inds.,* **19,** 76-77+ (1947) Oct.; *Corros. & Matl. Prot.,* **4,** No. 6, 26 (1947) Nov.-Dec.

Rusting of iron coils, used to refrigerate curing brine, is prevented by a special corrosion resistant paint.—INCO.

Protection of Steel by Pitch-Aluminum Paint. M. P. Peissi, Paper presented to the *Societe de Metallurgie,* (1947) Oct.

Pitch/aluminum paint with suitable fillers gave good results on a bridge for a period of 10 yrs.—RPI.

Ten Years' Outdoor Exposure of Filled Asphalt Coatings on Saturated Felts. G. L. Oliensis, *ASTM Bull.,* **144,** 32-41; discussion, 41-48 (1947).

Past exposure tests on filled coatings have been made on small rigid aluminum panels for relatively short periods under artificially produced weathering conditions. These tests have indicated that nearly all fillers improve the weatherability of asphalt. Present paper presents test data for asphalts coated on asphalt-saturated felt. The specimens were exposed out of doors for approx. 10 yrs., and results indicate that fillers do stabilize the flow and thereby improve the life of roofing cements which have a relatively low softening point; but fillers do not improve the crack resistance of coatings which have a high softening point and which do not flow when unfilled. Various grades of asphalt including those from Ark., Tex. and Venezuela were treated with and without fillers. The fillers used were dolomite, limestone, oyster shell and slate.

Temperature-Resistant Ceramic-Base Coatings for Metals. W. J. Plankenhorn & Terry F. Newkirk, *Ind. Heat.,* **14,** No. 2, 296-297 (1947).

Summary of Section VI of Report No. 16 of the Department of Ceramic Engineering of the University of Illinois.—MA.

New Method of Measuring the Thickness of Thin Coatings by Means of X-ray Photographs. F. Regier, *Off. Tech. Serv. Report* PB. L 17551-S41, 3 pp. *NPVL Absts.,* No. 126, 278 (1947).

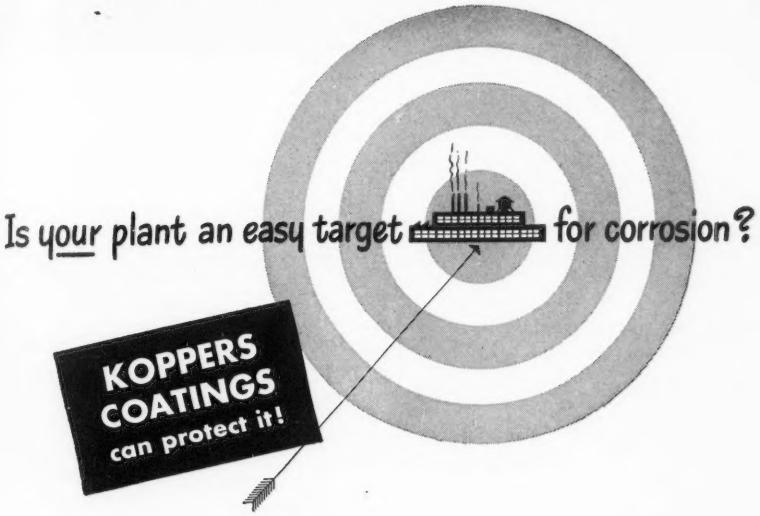
The article introduces briefly the existing methods of measuring the thickness of layers used as coatings by methods other than X-ray reflection and deals in detail with a new method in which X-rays incident at two angles on the surface of the layer are reflected from the coated body and their interference used for the measurement. A case of practical application of this method and its results are described.

Improvements in (Hot-Dip) Tinning. Howard C. Rodgers, *Iron & Steel Eng.,* **24,** No. 1, 65-66 (1947).

The hot-dip tinning process for cold-rolled steel strip has been improved by the introduction of vacuum feeding and electrolytic pickling.—MA.

Organic Coatings for Corrosion Protection. G. W. Seagren, Mellon Inst. of Industrial Research, Paper, before Sym. on Modern Metal Protection, Cleveland; abst. *Steel,* **121,** No. 18, 124-126 (1947) Nov. 11; *Corrosion* **4,** No. 5, 219-226 (1948) May.

The effectiveness of organic coatings



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for protecting metals depends on the continuity, adhesiveness, and non-permeability of the coatings as well as their corrosion resistance. The effect of moisture can be minimized by: (1) reducing permeability by the use of special pigments, (2) decreasing the corrosive effect of the permeating substance by the use of oxidizing pigments, such as red lead, (3) pretreating the metal, e.g., by phosphating, or (4) retarding corrosion by the use of pigments which are anodic with respect to the metal protected. Dissimilar metals in contact with each other, structures submerged in water, or complex structural designs which are difficult to coat well hinder satisfactory protection by organic coating.

Permeability and Corrosion in Protective Coatings. D. F. Siddall, *Corrosion*, **2**, No. 1, 78-84 (1946) Jan.; *NPVL* Abst., No. 125, 237 (1947).

The relationship of mol. size and shape, and of chemical and physical behavior, to permeability, is discussed. The permeability of a film is one of the important features governing its effectiveness for protection of substrates against attack, and should be considered, as well as resistance to chemical attack, in the selection of vehicles for protective coatings.—RPI.

Protective and Decorative Finishes for Cast Aluminum. John J. Stobie, Jr., *Modern Metals*, **3**, No. 4, 14-19.

Reviews the mechanical, chemical, electrochemical, and organic finishes available for cast aluminum. 27 ref.—MA.

Zinc as an Anti-Corrosive. A. H. Stuart, *Paint Mfr.*, **17**, 383-385 (1947) Nov.

Presents a possible mechanism by which zinc functions as an anti-corrosive pigment. Begins with a review of the phenomenon of ferrous corrosion.—BLR.

Porosity of Electrodeposited Metals, A. E. S. Research Project No. 6. I.—Bibliography. II.—Critical Literature Review. N. Thon & E. J. Addison, Jr., *Month. Rev. Am. Electroplaters' Soc.*, **34**, No. 4, 445-453; No. 5, 568-576 (1947).

(I.-) The bibliography covers the period from 1887 to early 1946. It contains 226 references, mostly to published work, but a few to unpublished private communications. It represents the preliminary step in the work of A.E.S. Research Project No. 6, and is confined to sources which make explicit contributions to the specific study of the nature and causes of the porosity which seems to be a systematic occurrence in metal electrodeposits. (II.-) A preliminary part of A.E.S. Research Project No. 6, preparatory to experimental and laboratory work. The early history of the problem of porosity in electrodeposited coatings is given briefly. This is followed by a discussion of the ferroxyl test.—MA.

Hot Plastic Paint. H. L. Aldrich, *Paint Oil & Chem. Rev.*, **110**, No. 2, 8+ (1947); *Brit. Absts.*, **BII**, 217 (1947) Aug.

Thick coatings of hot-applied plastic are effective as anti-fouling paints. The hulls are sand-blasted, sprayed with 2-5% H_3PO_4 solution, and primed with 2-3 coats of anti-corrosive paint (2-3 mils thick); the plastic (at 135-150°) is then sprayed on thickness 30 mils. The plastic must not sag in hot sunlight or be subject to plastic flow under conditions of use. If copper is used as an antifouling pigment, 10 mg./1000 cm^2 should be leached out in 24 hrs.—INCO.

Application of Microscope Techniques to the Examination of Paint and Varnish Films. *Paint Notes*, **2**, No. 4, 116-24.

A survey of the techniques for microscopical examination of paint films. 21 ref.—RPI.

Electrolytic Resistance in Evaluating Protective Merit of Coatings on Metals. R. Charles Bacon, Joseph J. Smith & Frank M. Rugg, Bakelite Corp., *Ind & Eng. Chem.* **40**, 161-167 (1948) Jan.

In the examination of over 300 test systems the electrolytic resistance of organic coatings on immersed metals has been found to be reliable for following protective behavior and for predicting coating life, generally, in less than one fifth of the time required by the usual exposure tests based on visual observation. These results are consistent with the assumption that the protection offered by underwater coatings is determined by the ease of passage of corrosive materials or ions through the coating to the corrodible metal surface, and that this diffusibility is in turn related to the electrolytic resistance of the coating. In measuring coating resistances the standard method for determination of the internal resistance of batteries was employed, the voltage being measured by means of an electronic potentiometer. As only exceedingly small currents are drawn and these only during the seconds of measurement, coating failure is not accelerated and the significant polarization is precluded.—CEC.

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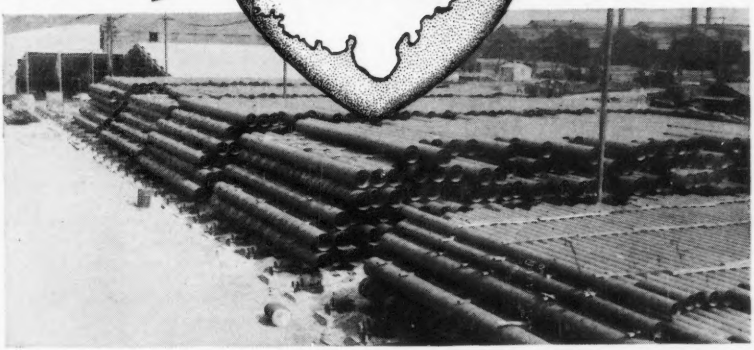

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CONSTRUCTION MATERIAL

Self-Priming Aluminum Centrifugal Pumps. *Mod. Metals*, **3**, No. 11, 24-25 (1947) Dec.

Marlow Pumps, Ridgewood, N. J., is now making five models in aluminum. A heat treated aluminum-silicon alloy was used which produced a sound, corrosion-resistant casting. Besides providing a clean smooth casting to give free-flow water passage through the pump, use of aluminum adds considerably to exterior appearance. Aluminum construction affords complete corrosion resistance to many types of liquid, including sea water. A weight saving of 17 lbs. results from the use of aluminum instead of cast iron.—ALL.

Aluminum Pipe. *Metal Inds.* (England), **72**, No. 1, 15 (1948) Jan. 2.

Reynolds Metals Company, in cooperation with some oil companies in the U. S. and abroad, is developing an aluminum pipe for the transportation of oil, natural gas and gasoline. One order was received from Argentina for a 1000-mile 10-inch aluminum pipeline for gasoline transportation. The use of aluminum pipe in the Far East for transportation of oil, natural gas and gasoline is also under investigation. Shortage of steel materials for pipelines led to this new use of aluminum.—ALL.

Carbon and Graphite. *Mach. Design*, **19**, No. 7, 157-160 (1947) July.

Properties, applications, fabrication, molding, methods of fastening, and design tips, with an extensive table giving chemical resistance of impervious carbon and impervious graphite (which are inert to all but highly oxidizing conditions) are briefly presented. Over 100 reagents are listed in the latter. Materials covered by property table are: carbon, graphite, carbon-graphite, metal-graphite, impervious carbon, impervious graphite, porous carbon and porous graphite. Apparent density, weight, tensile strength, compressive strength, transverse strength, elastic modulus, specific resistance, thermal expansion and thermal conductivity are given.—INCO.

Wire Products in Light Alloy. *Light Metals* (England), **11**, No. 120, 23-32 (1948) Jan.

Aluminum wire has been employed in large quantities for overhead transmission lines; in England it occurs chiefly in the form of unalloyed metal, but more recently, especially on the Continent, aluminum alloys have been used for the same purpose, this development being designed to take advantage of the somewhat higher strengths obtainable. Prior to 1939 about 1000 tons of wire were produced annually in England, chiefly for high-voltage overhead transmission lines. At the height of the war, output was 3000 tons annually, with a shift from the use of the pure metal to that of the stronger alloys, the product being used largely for aircraft rivets. The present operating rate is approximately 2500 tons annually, the bulk of the product being in the form of the pure metal for overhead lines, the remainder being in the form of alloy for aircraft rivets and some wire products. Fundamentally, aluminum wire and steel wire should be regarded as complementary rather than as purely competitive. The advantages of light-alloy wire are: a density of about one-third that of steel; an effective life frequently approximately three times that of equivalent steel wire under similar conditions. Light-alloy wire designed for special purposes lends itself readily to decoration by various specialized finishing processes. The International Wire Co., Ltd. has registered two types of wire under the name of "Nevarust" and "Litewire." "Nevarust" is recommended for outdoor use, as it has extreme resistance to atmospheric attack without any appreciable reduction in tensile strength. "Litewire" combines high tensile strength with workability without undue reduction of resistance to atmospheric attack.—ALL.

All Aluminum Cooling Systems in Aircraft. *Flight* (England), (1948) Jan. 22.

Work at the Rolls-Royce Flight Development Establishment has resulted in radiators of one-third the weight, with double the efficiency per square foot of area, at less than half the cost of those in existence ten years ago. The latest development is the all-aluminum secondary-surface radiator, which is half the weight of the previous best. The all-aluminum radiator has brought in turn an all-aluminum cooling system to obviate electrolytic action with other metals such as brass and copper. The system embraces oil coolers, intercoolers, header tanks and pipings, etc., and provides a marked reduction in installed weight. By installing such a system in the Tudor IV, British South American Airways effected a weight reduction which made possible the carrying of four extra passengers per trip.—ALL.

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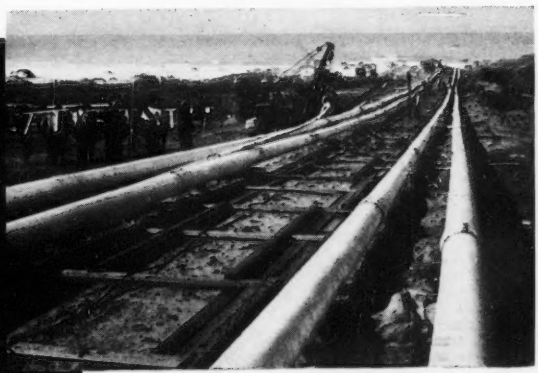

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Intermediate Alloy Steels at Elevated Temperatures. R. F. Miller, *Petro. Eng.*, 178, etc. (1948) Jan.

Development of the petroleum, chemical and power industries to a greater efficiency and economy depends to a considerable extent upon the use of higher and higher operating pressures and temperatures. In view of the requirements and possible safety hazards involved in this type of service, the steels used should have the following qualities: (a) Adequate strength at elevated temperatures; (b) resistance to oxidation and attack by the corroding media to which it may be exposed in service; (c) good ductility and toughness during its period of service; (d) weldability, if the application involves welding; (e) generally satisfactory fabrication characteristics, i.e., suitable for rolling, forging, or tube piercing. Tables list the steels most commonly used in the petroleum refining industry, together with their respective properties at elevated temperatures.—GPC.

Aluminum Piping: Where and Why It's Used. C. B. McLaughlin, *Heat., Piping & Air Cond.*, **20,** 87-89 (1948) Mar.

Explains why aluminum alloys are important piping materials for many industrial applications. Noteworthy properties of these metals are discussed and design precautions with respect to galvanic action, flexibility, insulation, gaskets, hangers, and supports are given.—BLR.

Chimney Liner Corrosion Resulting from Gas-Fired Furnaces. George B. Johnson, *Corrosion,* **4,** 15-23 (1948) Jan.

Presents results of a containing study of corrosion of actual installations in Minneapolis and of the effectiveness of different materials and coatings in resisting corrosion. Some discussion of aluminum liners.

Stainless Steel Powder. J. D. Dale, Charles Hardy, Inc., *Proc. 3rd Ann. Spring Mtg., Metal Powder Assoc.*, 1947, 4-13; *Powder Metall. Bull.*, **3,** No. 1, 14-15 (1948) Jan.

Findings of the Hardy Laboratory on physical properties and working conditions to obtain these in stainless steel powders are reported, with information on corrosion resistance of stainless steel filters from the Micro-Metallic Co. Graphs show results of sintering time, repress pressure and resinter time studies, tensile, elongation, linear shrinkage, and hardness vs. pressing pressure at varying conditions of resinter and cooling, and physical properties (tensile, elongation shrinkage and hardness) vs. pressing pressure. Predicted life of standard 18-8 alloy filter operating at 70° F. is 20 years in 68% nitric acid, 30 years in 10% nitric acid, 1.3 years in 96% sulfuric acid, 5 hours in 37% hydrochloric acid, 4 weeks in 1% hydrochloric acid, 10 years in 40% sodium hydroxide hydrogen, 20 years in 85% phosphoric acid and 40 weeks in 10% phosphoric acid. Cladding non-stainless surfaces with stainless steel by the Powder-weld Torch is very successful. An effective flux has been developed for addition to the powder to produce a clean bright metal or uniform structure and with good bond. Resistance to acids decreases, in general with amount of heat treatment. Reference to Swiss Sea Water Test.—INCO.

How to Combat Corrosion Through Design. Part I. Causes of Corrosion. Part II. Design Measures. (Concluded.) E. T. Collingsworth, Jr., *Mach. Design,* **20,** 116-122 (1948) Feb.; *Ibid.*, **20,** 142-148 (1948) Mar.

Part I reviews the fundamental principles of the different types of corrosion. Application to design is taken up in the second installment.—BLR.

FUNDAMENTALS

Corrosion of Metals with Oxygen Depolarization. *Light Metals,* **11,** 8-14 (1948) Jan.

Continues condensation, with commentary, of Russian book by N. D. Tomashoff. Present installment covers: analytical method for calculating rate of corrosion processes; and factors controlling rate of corrosion. (To be continued.)—BLR.

Corrosion of Metals with Oxygen Depolarization. (Continued.) *Light Metals,* 11, 104-112 (1948) Feb.

Continues condensation of Russian book by N. D. Tomashoff. Concludes section on theory and describes experimental technique used in investigation of corrosion mechanisms. A graphical method for computation of the rate of corrosion processes is first explained and then methods and equipment for study of the efficiency of different cathode materials are described and diagrammed. (To be continued.)—BLR.

Corrosion of Metals with Oxygen Depolarization. *Light Metals,* **10,** 637-645 (1947) Dec.

Begins condensation (with some commentary) of Russian book by N. D.

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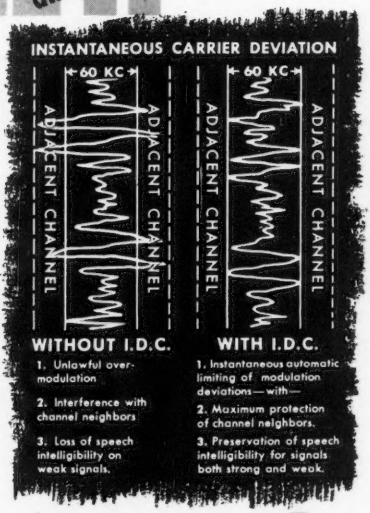

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Tomashoff, published by Academy of Sciences, Institute of Physical Chemistry, U.S.S.R., Moscow and Leningrad, 1947. All of the 70 figures will be reproduced. First installment discusses: fundamental problems of modern theory of the electrochemical corrosion of metals; local elements and corrosion; electrochemical hetterogeneity of the corroding surface; thermodynamics and velocity of corrosion; protective surface films; and factors determining the rate of the corrosion process. Later installments of this condensation will emphasize sections on corrosion of aluminum and magnesium and their alloys. (To be continued.)—BLR.

Influence of (Film) Defects and Foreign Inclusions on the Protective Action of Eloxal Films (On Aluminum Alloys). H. Röhrig & H. Käpernick, *Korros. u. Metallschutz,* **16,** 284-290 (1940); *Brit. Absts.,* **BI,** 170 (1947) May.

Eloxal anodic films on pure aluminum, aluminum-magnesium alloys and aluminum-copper alloy (Pantal) were damaged by scratching with a needle, abrading with emery powder, or by embedding sand grains, copper filings, or iron filings in them, and then tested in the DVL agitation apparatus in 3% aqueous sodium chloride containing 0.1% hydrogen peroxide. Cracks, scratches, non-metallic inclusions or partial removal of the film did not accelerate corrosion, nor set up a potential difference. Metallic inclusions caused marked local attack with undercutting of the oxide film or perforation of the sheet. With copper particles embedded in anodically oxidized aluminum-magnesium alloys the oxide film re-formed behind and around the copper particles, which often fell out.—INCO.

On the Composition and Infra - Red Spectrum of Oxide Films Electrolytically Produced on Aluminum Sulfuric Acid Compared to the Infra - Red Spectrum of Sulfates. *Helvetica Chimica Acta* (Switzerland), **30,** No. 7, 2010-2013 (1947); *Neuhausen Wochenbericht* (Switzerland), **32,** 5 (1947) Dec. 12-31.

Anodic oxide films deposited on aluminum in sulfuric acid contain water which may be eliminated by drying or by the heat of annealing and with it a considerable quantity of sulfuric acid. Infra-red absorption studies show that water occurs either in the form of H_2O molecules as water of hydration or in the hydroxide form. The question arises whether—depending on the growth of the film—hydroxide and hydrate occur in two layers, one above the other. Comparisons with infra-red studies on calcium sulfate show that certain absorption bands determined in aluminum oxide films result from the sulfuric acid content.—ALL.

The Rate of Oxidation of Nickel with Low Chromium and Manganese Additions. Contribution to the Theory of the Tarnishing Process. (In German.) Carl Wagner & Karl-Erik Zimens, *Acta Chemica Scandinavica,* **1,** 547-565 (1947).

Includes both experimental data and a theoretical development. The rate of oxidation of nickel is markedly increased by small additions of chromium or manganese. Mixed oxide phases containing increased bivalent-nickel concentrations are formed. The forces causing migration in such phases are analyzed. In nickel-chromium alloys with high chromium content, the rate of oxidation decreases considerably. By analogy with other systems, it is assumed that a new phase with low ion motion is formed. 31 ref.—BLR.

Relationships of the Phases in Systems of Water Solutions and Metals. (In Russian.) A. I. Shultin, *Zhurnal Prikladnoi Khimii (J. Applied Chem.),* **20,** 739-753 (1947) Aug.

An extensive experimental investigation revealed that the oxidation-reduction properties of solutions depend not only upon the nature of the dissolved substance but also upon the pH. The chart of pH vs. Redox potential is used to estimate the corrosivity of different solutions toward different metals.—BLR.

Activation of Passive Iron. W. H. Cone, Univ. of Idaho, and D. H. Anderson, Eastman Kodak Co., *Corros. & Matl. Prot.,* **4,** No. 4, 21-23 (1947) July-Aug.

Passivity of iron can be due to an adsorbed layer of gas which can be O_2 and it is felt that in the chromic acid electrolyte solutions studied this was the gas adsorbed. This gas layer can be disturbed and, if the conditions in the solution do not lead to reformation of the layer, the iron will become and remain active. The gas layer was disturbed by lowering the partial pressure of the O_2 and this resulted in activation. The layer was also disturbed by rapid rotation of a passive iron rod. Activation was observed to take place above a rather definite speed, and this speed was found to be a function of the temperature. In view of the ease with which activation can be established, the authors do not consider it necessary to postulate the existence of an oxide film on the iron. 4 ref.—INCO.

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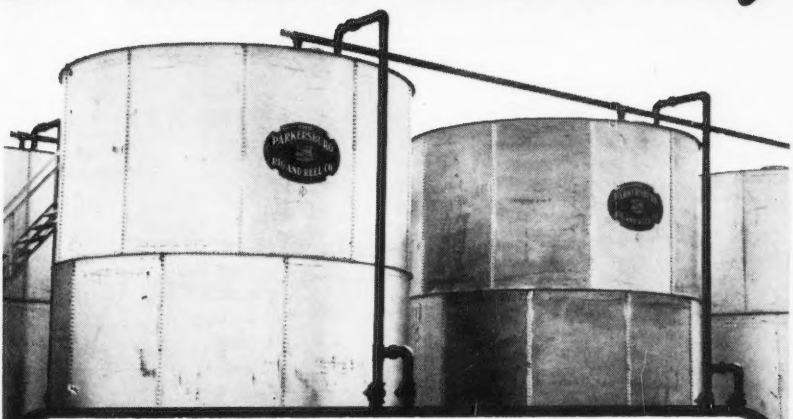

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A New Concept About the Mechanism of Passivity of Iron in Nitric Acid. R. Parshad & L. C. Verman, *J. Chem. Physics*, **16**, 154-155 (1948) Feb.

Presents experimental evidence which supports the theory of the formation of a hydrogen film between the metal and the oxide film. This is indicated by a sharp rise in potential on insertion of iron in nitric acid, which falls to a much lower potential after about 0.05 sec. This theory explains many phenomena associated with passivity.—BLR.

Oxidation of Metals. (In French.) N. F. Mott, *J. de Chimnie Physique et de Physico-Chimnie Biologique*, **44**, 172-180 (1947) Aug.-Sept.

Assumes that metallic ions pass through the oxide layer to react with oxygen on the surface of the layer. This idea is examined mathematically for a compact metal film, either amorphous or crystalline. 13 ref.—BLR.

A Study of Films Isolated from Passive Stainless Steels. E. M. Mahle & N. A. Nielsen, E. I. du Pont de Nemours & Co., Paper before Electrochem. Soc., Columbus, Ohio, Mtg., April 14-17, 1948; *J. Electrochem. Soc.*, **93**, No. 1, 1-16 (1948) Jan.

By use of a bromine-methanol solution, passive films were isolated from electrolytic chromium, Types 430, 304 and 317 stainless steel, Nichrome V and Inconel. The films, very thin and transparent, were found to be formed on initially film-free (pickled) surfaces by air exposure and by passivation treatments in HNO_3 and in HNO_3-$K_2Cr_2O_7$ solutions. These passive films were examined by both light microscopy and electron microscopy and electron diffraction. Chemical analyses indicate that both chromium and iron are major constituents in the films from Types 430 and 317 stainless steel. These are believed to be present together in solid solution, possibly in a spinel type of crystalline lattice. The films from chromium passivated in HNO_3 were shown to contain a high percentage of chromium, possibly as Cr_2O_3. Stripping experiments with Nichrome V and Inconel exposed to air after pickling or passivated in HNO_3 or HNO_3-$K_2Cr_2O_7$ solutions were also successful in isolating very thin surface oxide films. It was noted by the corrosive action of the bromine-methanol that the air-exposed specimens had least corrosion resistance to the reagent and the film formed by the HNO_3-$K_2Cr_2O_7$ treatment was most protective and adherent to the base metal. No further work was done in studying passive films from these alloys, and physical and chemical nature of the films was not determined.—INCO.

Thin Films and Surfaces. Winifred Lewis, *English Universities Press, Ltd.*, London, Ed. 1, 70 pages.

The first part of this monograph attempts to outline what is known up to the present about the structure and properties of thin films and surfaces in general. Chapter IV deals with the production of thin films. The last two chapters collect information relevant to the properties of aluminum, briefly summarize some comparative data for other metals, and describe some applications. Does not cover electroplated films. 242 ref.—BLR.

GENERAL CORROSION

British Non-Ferrous Metals Research Associations; Twenty-Seventh Annual Report. *BNMRA* (London), 45 pages (1947).

Contains general report, review of research progress, researches in progress, reports available, and membership information.—BLR.

The Problem of Metal Corrosion. (In Spanish.) Emilio Jimeno, *Ministerio de Marina, Institute Espanol de Oceanografia*, Madrid, Spain, 237 pages (1947).

Discusses importance of metal corrosion and theories behind it and attempts to apply the electron theory to explain numerous phenomena inexplicable otherwise. The electrochemical nature of corrosion is covered in detail. Effects of humidity, temperature changes, and various attacking agents, including organisms and incrustations are mentioned. Means of protection against attack, both external and internal, are given. The study was made in cooperation with the Spanish Institute for Oceanography.—BLR.

Experimental Work Carried Out at the British Cast Iron Research Association. J. Bernstein, *J. Iron & Steel Inst.*, **15**, 20-36 (1948) Jan.

The characteristic microstructure of of peeled samples of whiteheart malleable cast iron is described, and it is shown that the prime cause of peeling is the inward penetration of sulfur from the annealing ore or from sulfur-containing gases in the annealing atmosphere. Factors affecting depth of the peeled layer are enumerated. Peeling is demonstrated to be a complex phenomenon involving decarburization, sulfurization, and inward penetration of oxygen; desulfurization may also occur. The diffusion processes involved are discussed. 10 ref.—BLR.

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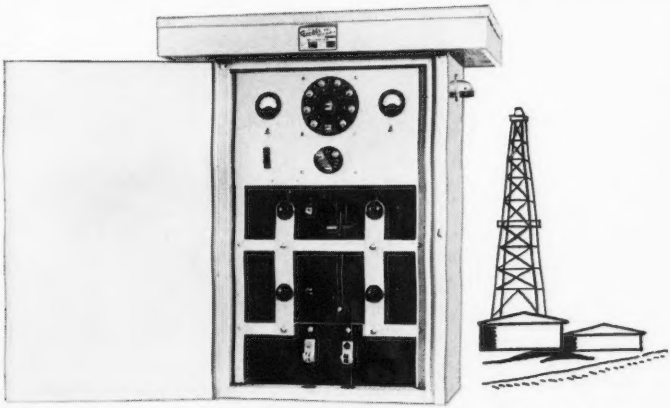

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INHIBITORS

Passivity of Chromium. Norman Hackerman & D. I. Marshall, *J. Electrochem. Soc.*, **93,** 49-54 (1948) Mar.

Surfaces of chromium, treated with nitric acid and then oxidized in air at various temperatures, were examined by electron diffraction and results correlated with results of electrode-potential measurements on other samples subjected to the same treatments. Air-passivation treatment was compared with nitric acid passivation. Results are charted and discussed. It was concluded that an oxide film is not the fundamental criterion of passivity in the case of chromium; but that the presence of such a film can greatly influence the potential.—BLR.

Note on Inhibitors and Their Application in Pickling. (In Swedish), S. V. Ekstrom, *Finish* (Sweden), **4,** 220-222 (1947) Oct.

Discusses effect of adding inhibitors to pickling baths for steel. The composition of the baths claimed to be most effective is given.—BLR.

Inhibition of Steel Corrosion by Sodium Nitrite in Water. Morris Cohen, *J. Electrochem. Soc.*, **93,** 26-39 (1948) Jan.

Presents results of a study of the above test methods which included total and alternate immersion, a recirculation apparatus, and potential measurements. The concentration required to inhibit steel corrosion depends on conditions of motion and temperature and the inhibiting effect can be interpreted by solution-potential measurements. The mechanism of inhibition is believed to be the formation of a protective oxide coating.—BLR.

Nitrogen-Containing Organic Inhibitors of Corrosion. S. Ch'iau & C. A. Mann, *Thesis for Ph.D. at Univ. of Minnesota,* Dec., 1945; *Eng. & Eng. Chem.*, **39,** No. 7, 910-919 (1947) July.

Nitrogen-containing organic inhibitors, such as anilines, pyridines, quinolines and acridines, are cathodically absorbed on metal surfaces. They reduce the available cathode area for the evolution of H_2, but do not, as do cathodic inhibitors of inorganic compounds (such as antimony and arsenic salts), actually change the nature of the cathode. A quantitative relation between the cathode potential rise with addition of inhibitor and its inhibition efficiency is proved. Molecular mechanism is discussed, with reference to Traube's rule of adsorption. The usefulness of many nitrogen-inhibitors, which are not very soluble in acid solutions, can be improved by the saturation of the nucleus. Arrangement of apparatus for cathode potential and measurement is shown. Cathode potential of mild steel in normal sulfuric acid with various inhibitors is graphed. 28 ref.—INCO.

INSPECTION

Plastic Replicas for Surface-Finish Measurement. Part I. J. Pearson & M. R. Hopkins, *J. Iron & Steel Inst.* (England), **158,** 138 (1948) Jan.; *Light Metals Research* (England) **9,** No. 2, 39 (1948) Jan. 21.

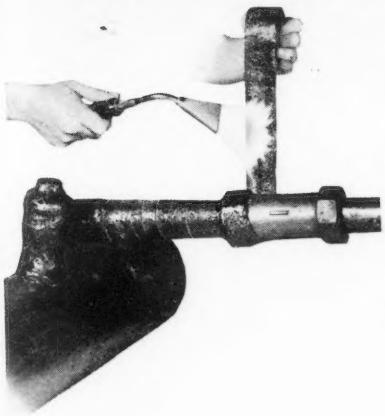
Plastic replicas of the micro-structure of a surface may be made by the following method, developed jointly by ICI. (Plastics), Ltd., and the British Iron and Steel Research Association: the replicas are hard enough for roughness measurements by stylus instruments ("Talysurf") and their preparation does not involve heating the specimen. One drop of a homogeneous liquid mixture of monomeric and polymerized methyl methacrylate, containing an organic ester as stripping agent and small proportions of a photo-chemical catalyst, is placed on the surface and a "Perspex" sheet (1 in. x 1 in. x ⅛ in.) pressed down over it. The back of the "Perspex" is then irradiated 1 hr. by a mercury-vapor lamp emitting the required ultraviolet radiation, and the specimen then stripped from the metal. "Talysurf" measurements show good correlation between the roughness of the original surface and that of the hardened replica.—ALL.

Thickness Testing: Electrochemical Jet Method for Local Thickness of Electrodeposits on Metals. A. Ogarev, *Electroplating,* **1,** No. 2, 54-60 (1947) Dec.; Translation, *Zh. Prikladnoy Khimii,* **19,** No. 3, 311-315 (1946).

In the test described, the jet of solution forms part of an electric circuit, the part under test being anodic; a change in the current indicates end-point. Same solution could be used for testing chromium, nickel, copper, tin, zinc, and cadmium, and result is claimed to be independent of temperature. Solution can be used repeatedly.—BNF.

A Visual Aid for Inside Inspection of Drill Pipe; Third Progress Report on Non-Destructive Testing of Drill Pipe. L. R. Jackson & others, *Drilling Contr.*, **4,** 58-60 (1948) Feb. 15.

Describes a simple optical device which consists essentially of a sectional pole car-



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rying a light source and a 45-degree conical mirror. Such devices may be constructed quickly and at low cost, are light-weight and portable, and provide clear images of the defects. They provide means for inside-inspection intermediate betwen crude visual inspection with a spotlight, and detailed inspection with an expensive borescope.—BLR.

METAL FAILURE

Hydrogen Embrittlement of Steel. Parts I, II, and III. *Metal Ind.*, **71,** No. 14, 288 (1947) Oct. 3; *Ibid.*, No. 16, 325, 329 (1947) Oct. 17; *Ibid.*, No. 18, 366 (1947) Oct. 31.

Review article giving main established facts on hydrogen absorption by steel, its results and various theories. Controversy over theory of Zapffe and Sims is reported with reactions of Syles, Burton, and Gegg and others. Tests forming the basis of J. H. Anrews and H. Lee's conception of the "rift" theory are described. —INCO.

Stress Corrosion in Materials. (In German.) *Matl. & Meth.*, **27,** No. 1, 107-108 (1948) Jan.

Composite abstract of: **The Cause of the Sensitivity to Stress Corrosion of Homogeneous Alloys.** L. Graf, *Metallforschung.*, **2,** 193-207 (1947) July-Aug.; **On the Stress Corrosion of Heterogeneous Alloys,** L. Graf, *ibid.*, 207-212; **On the Effect of Stress on the Danger of Failure by Stress Corrosion.** K. Matthaes, *ibid.*, 213-225.

There is no lower limit of stress below which a sensitive metal can be considered absolutely resistant to stress corrosion. Practically, the life increases so markedly at lower stresses that a satisfactory degree of safety can be reached. Notches do not increase danger of failure by stress corrosion. Magnitude of stress is as important as influence of corrosive medium or condition of material, and a failure similar to that due to fatigue or corrosion fatigue. In tests to clarify the danger of failure under conditions of stress other than tensile stresses, failure always occurred as a normal stress (tensile) failure with rupture planes perpendicular to direction of main tensile stress. *The following rules apply to stress corrosion of homogeneous solid solutions:* 1) Stress corrosion can be caused only by a corrosive medium that attacks the solid solution. 2) Greatest danger exists with solid solutions based on an element less noble than the alloying element which composes the smaller portion of solid solution. 3) Danger of stress corrosion also exists for solid solutions based on an element nobler than the alloying

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element, but in this case, danger depends to a large extent on type of corrosive medium. The possibility of producing homogeneous alloys insensitive to stress corrosion is confined principally to alloys based on gold, platinum and palladium. Silver alloys are insensitive only when they contain less noble alloys. *Heterogeneous alloys follow the same general rules,* the individual phases being sensitive or not according to the rules. If there is only a small amount of one phase, the behavior depends on the chemical resistivity and sensitivity to stress corrosion of minor phase. If about equal amounts of two phases exist, occurrence of stress corrosion is function of various factors, including the relative amounts of the two phases, electrochemical potential difference between them, and the type of corrosive medium—INCO.

Fretting Corrosion. *Lubrication,* **34,** 25-36 (1948) Mar.

The above is a particular type of corrosion found on the contact areas of loaded metal surfaces subject to oscillatory or vibrating motion. The phenomenon is also known as "false brinelling" and as "friction oxidation." Reviews work which has been done on this problem, which is still far from complete solution. Photographs illustrate numerous examples. The nature of the process, the effects of load, surface finish, and materials are discussed and some suggested remedies are presented, including use of lubricants.—BLR.

SURFACE PREPARATION

Surface Conditioning and Temporary Protection. *Paint* (England), **18,** No. 254 (1948) Feb.

The Bakelite Corporation in conjunction with the U. S. Navy Bureau of Ships, has developed a vinyl resin-base wash primer which functions both as a metal surface conditioning agent and as a priming coat for temporary protection prior to painting, and which provides outstanding adhesion to steel, galvanized iron, aluminum (anodized and unanodized), and other metals. The wash primer is a solution of a vinyl-butyral resin in alcohol pigmented with a relatively insoluble zinc chromate and reacted with phosphoric acid. Since the vinyl-butyral resin is not dependent on either oxidation or polymerization for hardening, subsequent coats of paint may be applied as soon as the solvent has partially evaporated—usually 10 to 20 min. Optimum film thickness ranges from 0.3 to 0.5 mils, and therefore the coating should not be regarded as an anti-corrosive primer which will withstand extreme or prolonged attack. It does, however, prevent the spread of corrosion under the paint film, thus fortifying the entire paint system. Applications may be made over wide temperature ranges as long as temperature and method of application are considered in choosing the alcohol used as the solvent. The coating is applied by any of the standard methods.—ALL.

The Effect of Surface Finish on the Fatigue Performance of Certain Propeller Materials. H. W. Russell, H. W. Gillett, L. R. Jackson & G. M. Foley, Battelle Memorial Inst., *NACA Tech. Notes,* No. 917, 18 pp. (1943) Dec.

The effect of various surface finishes on endurance of normalized SAE 4130 and 4140 steels and 25S-T aluminum alloy was investigated at Battelle. Smoothness of surface was found less important than other surface properties, and all mechanically formed surfaces were stronger than electro-polished ones. Conclusion is that a smooth, electropolished surface is an unstrengthened one, and that removal of damaged surface by electropolishing is not so effective as mechanical polishing in prolonging life. Tables, graphs and photomicrographs.—INCO.

Aluminum Anonizing Process. *Chem. Inds.,* **62,** No. 1, 86, 88 (1948) Jan.

A new process for the protection of aluminum surfaces without changing from the natural aluminum color which appears to be an improvement over the expensive anodizing technique and that of clear lacquering, which is not very adherent, is the anonizing process. Developed by the Technical Processes Division of Colonial Alloys Co., this is a simple immersion method which can be applied to aluminum that has been etched, polished, or left as milled, without noticeably changing the appearance. Practically all of the alloys of aluminum respond to this treatment and most of them maintain or even improve their original surface color. The coating resembles a clear glaze similar to an anodized coat (aluminum oxide) but it is more compact. Anonized surfaces have good abrasion resistance and are resistant to smudging, oxidizing, finger marks, ordinary handling and high temperatures. They present an excellent base for paints and lacquers. The process consists of immersing the cleaned aluminum into the hot anonizing solution for a few seconds

to a few minutes, then rinsing. The equipment can be ordinary steel and many items can be handled in a batch. Many articles can be treated for as low as one-fifth of a cent per square foot of area processed.—ALL.

Finishing Metals by "Liquid Honing." Charles H. Wick, *Mach.*, **54,** 158-161 (1948) Mar.

Describes and illustrates use of abrasive suspended in a water-chemical solution and discharged from a nozzle by compressed air. Some remarkable increases in the life of cutting tools, molds, and dies have been obtained in this way.—BLR.

The Electrolytic Polishing of Metals. G. Tolley, *Metallurgia* (England), **37,** No. 218, 71-74 (1947) Dec.

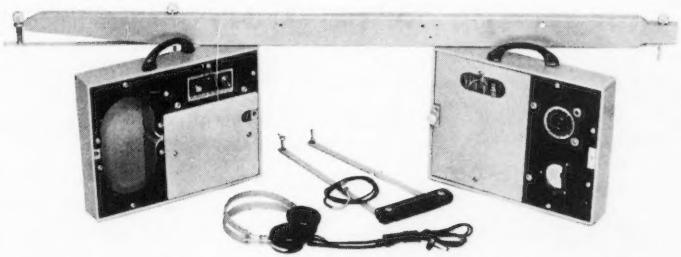
Reviews the advantages of the electrolytic polishing method over the mechanical method, as well as the many reliable electrolytic methods in use today. The most frequent application is in finishing for appearance, where brilliance and color tone can be achieved to exceed that possible by mechanical methods. The best results are obtained on shaped parts and generally, the process is more economical when applied to supplement mechanical polishing. Attention is directed to the application of the process in metallography as well as in the finish of products. The industrial and laboratory methods for polishing metals including aluminum are listed and discussed in a practical manner.—ALL.

Surface Treatment of Metals Before Painting. R. E. Gwyther, *Product Eng.*, **18,** No. 3, 153-5 (1947); *Paint Var. Prod. Man.*, **27,** No. 12, 343 (1947).

Methods of preparing metal surfaces prior to painting are discussed. Techniques of coating, rinsing, and cleaning for improved paint adhesion and resistance to weathering are included, together with recommended types of chemical solvents for soil and scale removal.—RPI.

Polishing of Metals. R. Sansone, *Chem. & Eng. News*, **26,** No. 8, 573 (1948) Feb. 23.

A study has been conducted at the Electrochemical Institute of Milan on anodic processes for the electrolytic polishing of metals. Distribution of current was controlled, uniformity of temperature at-



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tained, and means of studying the progress of anodic tension discovered. With particular reference to the polishing processes for small copper surfaces, using o-phosphoric baths (the Jacquet process), anodic tension curves were observed over a period of time with a constant current density and, also, using oscillographic methods. The results of the experiments called for further investigation of processes of this type concerned with copper, which under analogous conditions can also be of value for other metals. When the geometrical and selectivity conceptions that are the basis of the anodic attack have been introduced, the most favorable conditions for electrolytic polishing are found to correspond to an elevated geometrical selectivity, or, in other words, to a low anodic penetration power of the baths.—ALL.

TESTING

Variables in Exposure Testing. *Paint Notes*, **2**, No. 3, 78-9 (1947).

Details of accelerated breakdown schedules for outdoor exposure are given in this note. Panels are exposed facing north at an angle corresponding with the reception of maximum sunlight and sprayed with water 3 times daily. The program described is intended to evaluate (a) relative severity of exposure during various seasons of the year. (b) comparison of severity of exposure on different types of racks, etc., (c) comparison of severity of exposure conditions in Melbourne and Sydney.—RPI.

Ocean Put in Test Tube at Kure Beach. The International Nickel Co., Inc., *Inco*, **21**, No. 4, 4-9 (1947).

A detailed account of this American corrosion testing station where numerous materials are now under investigation. Maintenance and development costs are shared by The International Nickel Co. and The Dow Chemical Co.—BNF.

Weathering Machine Correlation in the Cleveland Club and Other Areas, Part I. Cleveland Paint & Varnish Prod. Club, *Am. Paint J., Convention Daily*, **32**, No. 7B, 8, 11-15 (1947).

The work described earlier (Review, Current Literature of Paint Inc., 1946, 120; 1947, 215) has been continued. Six different finishes on steel panels were exposed in one of two types of weatherometer at

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seven localities. Strips were cut off the panels at intervals of 3, 7, 11, 16 and 21 days, and the results of exposure assessed by physical testing in terms of paint failure rather than through analysis of weather factors. Thus, heating effects were revealed by measurement of elongation, chalking and loss of gloss, and water effects by adhesion and rusting; color change was influenced by both water and heat. The data are presented graphically and the modifications necessary to bring the tests to the Florida level are: (1) treatment of the water used if consistent results from like machines are to be obtained when operating at different localities, (2) a longer water exposure, (3) the attainment of a max. temperature of 145± 5° F. (cf. Review, 1947, 294) which must be maintained in the panel for half the total period of irradiation.—RPI.

A Note on the Preparation, Suspension and Testing of Corrosion Specimens. W. Murray, *J. Iron & Steel Inst.*, **158,** 200 (1948) Feb.

In the course of experiments on the inhibition of corrosion of metals completely immersed in water, the duplication of results was found to be impossible. Modifications in the method of preparation and suspension of specimens overcame the difficulty, hence the improved method is described and diagrammed. Covers both single-metal and bi-metallic specimens and testing at 90° F.—BLR.

UNDERGROUND CORROSION

Control of External Corrosion on Plantation Pipe Line. Alan C. Nelson, *Corrosion,* **4,** 123-131; discussion, 132 (1948) Mar.

Corrosion control on the above system is divided into four major phases. First is cathodic protection of stations which have suffered numerous leaks in small control lines. Second is cathodic protection of tank bottoms. Third is cathodic protection of the main line with its numerous spots of coating. Fourth, is drainage of strong, fluctuating stray current at a number of electric-railway crossings.—BLR.

Utilization of Electrically Insulated Couplings in Corrosion Control. W. F. Levert, *Corrosion,* **4,** 24-28 (1948) Jan.

Describes and diagrams above method which is said to be very useful and economical in practice. By this means, it is possible to isolate sections of pipe lines

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which lie in corrosive soil and apply cathodic protection to them only. Also installation of the couplings at intervals along a pipeline breaks up long-line currents, which are very detrimental.—BLR.

WATER CORROSION

Combating Scale Formation. R. B. Walter, *World Oil*, Vol. No. 119 (1948) Jan.

A metallic treater consisting of an iron rod on which are strung alternate copper and zinc plates has found application in reducing scale or "gyp" formation in oil field emulsion treaters and boilers. The rod is immersed in the fluid and the scale-forming elements attack the zinc, setting up an electro-motive action which results in precipitating the corroding scale and prevents its encrustation within the pressure vessels. It has also been found applicable in reducing scale on pumps, rods and tubing.—GPC.

Bronze and Sea-Water Corrosion. Anon. *Tin and Its Uses*, No. 18, 9-11 (1947) July.

Usefulness of tin bronzes containing 10% or more tin is reported with results of jet impingement tests comparing 70-30 brass, Admiralty brass, aluminum-brass, 70-30 copper-nickel, 10% tin-1% aluminum bronze, and 10-, 12-, and 14% tin bronzes. The latter three alloys showed no attack. In sedimentation tests (immersion in aerated sea water while partially covered by sand) of 2% aluminum-brass, 70-30 copper-nickel, 10- and 13% tin bronze, no one alloy was superior. Apparatus for the impingement and sedimentation tests is shown. Graphs give result of sedimentation test. Researches into casting of bronze in chill moulds proves that bronze containing 8-14% tin can be hot forged, extruded, stamped or cold drawn or rolled. The superiority of the 10% tin bronze is caused by the complete dissolution of tin due to elimination of dissolved gases in molten metal. —INCO.

Soluble Silicates for Corrosion Inhibition in the Oil Industry. Wm. Stericker, *Corrosion*, 4, 83-92 (1948) Feb.

Presents a number of case histories and draws conclusions from them which will serve as guides in the use of silicates elsewhere.—BLR.

In Bulletin 1, The Correlating Committee On Cathodic Protection Of The NACE Says

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